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DEPARTMENT BULLETINS

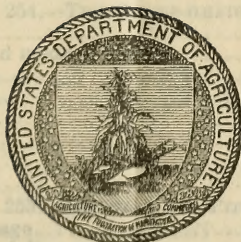
Nos. 251-275,

WITH CONTENTS AND INDEX.

PREPARED UNDER THE SUPERVISION OF

JOS. A. ARNOLD,

EDITOR AND CHIEF.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

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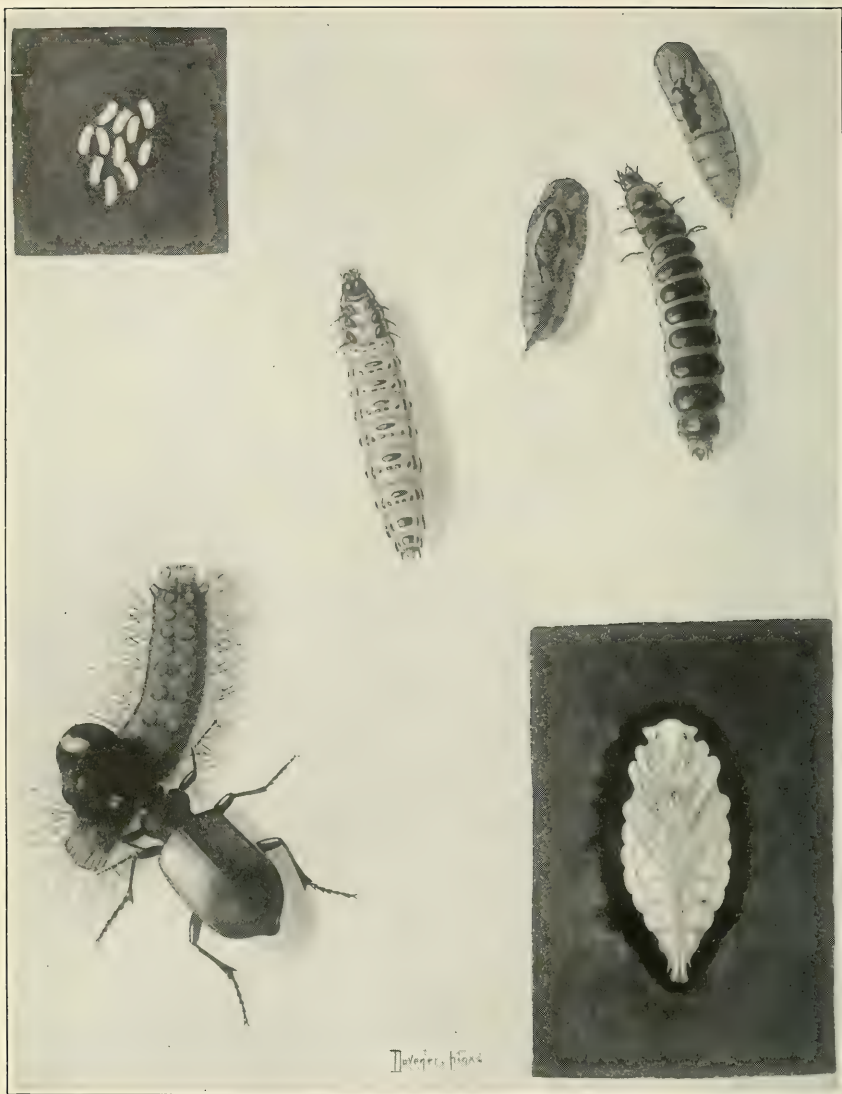
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THE CALOSOMA BEETLE (*CALOSOMA SYCOPHANTA*).

Upper left, eggs; lower left, adult beetle feeding on gipsy moth caterpillar; upper right, gipsy moth pupæ destroyed by *Calosoma* larvæ; center, *Calosoma* larva, ventral view; right center, *Calosoma* larva, dorsal view; lower right, *Calosoma* pupa in cavity in ground. (From Howard and Fiske.)



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L. O. HOWARD, Chief

Washington, D. C.



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THE CALOSOMA BEETLE (CALOSOMA SYCOPHANTA) IN NEW ENGLAND.

By A. F. BURGESS, *In Charge of Gipsy Moth and Brown-Tail Moth Investigations*,
and C. W. COLLINS, *Entomological Assistant*.

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INTRODUCTION.

In the spring of 1905 an arrangement was made by the United States Department of Agriculture to cooperate with the State of Massachusetts in importing and establishing the natural enemies of the gipsy moth and the brown-tail moth. Dr. L. O. Howard, Chief of the Bureau of Entomology, supervised the work, and until December 1, 1911, this arrangement remained in force, the project being financed jointly by the Bureau of Entomology and the State of Massachusetts. Since 1912, owing to the fact that the scope of the work involved nearly all of the New England States, these projects have been carried on solely by the Bureau of Entomology.

One of the natural enemies of the gipsy moth, which has long been known in Europe as of prime importance, is a green beetle be-

NOTE.—The writers wish to acknowledge their obligation to the members of the staff at the Gipsy Moth Laboratory for securing data and carrying on many of the experiments which are only briefly alluded to in this publication. There is hardly a man who has been connected with the laboratory for the past seven years who has not assisted to a greater or less extent in obtaining information and securing some of the results already mentioned. So many have assisted in this work that it is impossible to name each individual, but the writers wish to express their appreciation to all those who have taken part in the work.

longing to the family Carabidæ, and known to science as *Calosoma sycophanta* L. (Pl. I.) This species was collected and shipped to Massachusetts, as a result of arrangements made by Dr. Howard with numerous European collectors of insects, more particularly with Miss Marie Rühl, of Zurich, Switzerland. Several other closely related species of *Calosoma* were collected and some of these were received in sufficient numbers to permit of colonies being liberated in woodland infested with the gipsy moth. Several species of the allied genus *Carabus* were obtained and similarly liberated.

Up to the present time the only species that is known to have maintained itself is *Calosoma sycophanta*, and this insect has increased so enormously as to become an effective enemy of the gipsy moth in this country.

Table I gives the number of live specimens of *Calosoma sycophanta* which have been imported from Europe. Sixty-seven per cent of these beetles were liberated in the field and the balance were used for experimental and reproduction work. All the beneficial results secured in the field have accrued from about 4,000 beetles noted in the table.

TABLE I.—Number of living specimens of *Calosoma sycophanta* received from Europe.

Year.	Number received.	Year.	Number received.
1905.....	1	1909.....	405
1906.....	693	1910.....	1,305
1907.....	967		
1908.....	675	Total.....	4,046

METHODS OF PACKING BEETLES FOR SHIPMENT.

Different plans covering the packing of these beetles for shipment were tested during the years above mentioned. The most satisfactory arrangement was to pack the beetles singly in small safety-match boxes which contained a quantity of wet sphagnum moss. These boxes were packed in a larger wooden box (fig. 1), the usual size being $7\frac{1}{4}$ by 4 by $2\frac{1}{4}$ inches. A shipping label was glued to the box. Material packed in this manner was shipped by mail and received in good condition. Experience has shown that the greatest cause of mortality in shipping these beetles is due to lack of moisture. When sufficient moisture is provided no difficulty is experienced, and it is not necessary to place food of any kind in the boxes. As a rule, these shipments were en route from 10 to 12 days. In case beetles are to be forwarded and will not be in transit more than 2 days, several can be placed in a box and shipped by ordinary mail with very little injury resulting.

NATIVE HOME OF CALOSOMA SYCOPHANTA AND HOSTS ATTACKED.

This insect is known to occur in France, Germany, Switzerland, Italy, and other European countries, being particularly abundant in cases where there are unusual outbreaks of destructive caterpillars. Its good work is mentioned in a number of European writings, and it is known to prey extensively on the gipsy moth (*Porthetria dispar* L.) and the pine sawfly (*Lophyrus pini* L.). As early as 1736 Reaumur published a general account of the life history of the species, and valuable information has been published by M. G. de la Pougé concerning his investigations of the larvæ of this insect.

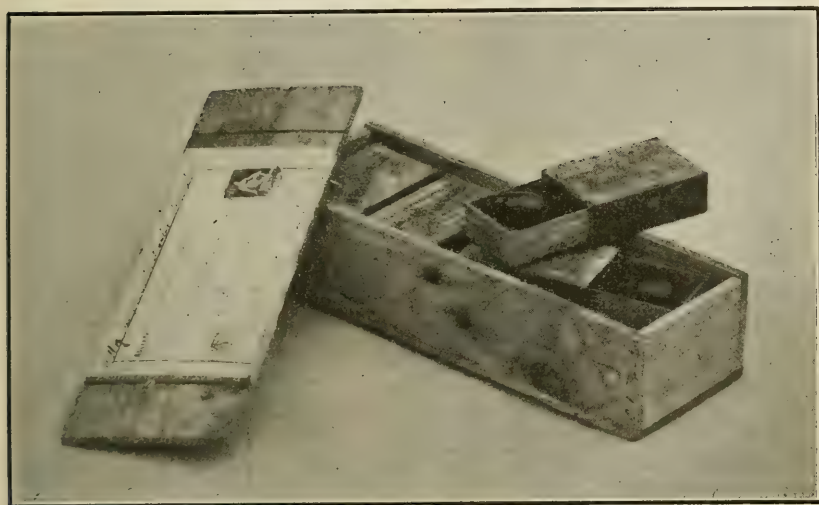


FIG. 1.—Shipping box, with cover removed to show method of packing *Calosoma* beetles. Each match box contains a single beetle and a small quantity of wet sphagnum moss. (From Burgess.)

INVESTIGATIONAL WORK ON CALOSOMA SYCOPHANTA.

The year 1906 was the first in which these beetles were received in large enough numbers that colonies might be liberated or a study made of their habits. During that year considerable work was carried on by Mr. E. S. G. Titus and Mr. F. H. Mosher, and notes and observations on the behavior of the species in large breeding cages were made by Mr. R. L. Webster. During the following summer the work was placed in charge of the senior author, and since that time detailed experiments have been conducted. Mr. C. W. Collins has assisted with this work during the entire period and for the past two or three years has planned and executed many of the experiments.

EQUIPMENT USED FOR REARING PREDACEOUS BEETLES.

Experiments have shown that *Calosoma* beetles, in common with most other insects, thrive when they are kept under natural conditions. Fair success may be secured through rearing experiments in a laboratory, but as the beetles are most active, both concerning feeding and reproduction, during hot weather, and as it is important to regulate the soil moisture if best results are to be secured, it has been found decidedly advantageous to use an outdoor insectary for work of this description. An insectary such as is in use at the Gipsy Moth Laboratory, Melrose Highlands, Mass. (Pl. II), is inexpensive and will last a number of years. We have used a cement foundation on which was erected a frame constructed of 2 by 4 studding. The exterior walls have been covered with fine-mesh wire netting and the roof is canvas. A coating of white lead applied to the canvas will make it last longer, and if the netting walls are painted annually with black screen paint to prevent corrosion, they will not need to be renewed for two or three years. Copper-wire netting can be substituted for the walls and does not require paint. The insectary is provided with outside canvas curtains which may be rolled up in order to regulate the amount of sunlight or keep out rain; awnings could be used for this purpose if desired. Shelves, benches, or tables may be added as necessary. A building of this description fairly approximates outdoor conditions and has given very satisfactory service. (Pl. III.)

Beetles of this genus deposit their eggs in the ground. They also conceal themselves for a part of the time beneath litter or rubbish. The best results with *sycophanta* have been secured by using battery jars $8\frac{1}{2}$ inches tall and $6\frac{1}{2}$ inches in diameter (fig. 2), but a size slightly smaller will give as satisfactory results. Circular wooden tops are used to cover these jars, which are grooved to hold the top in place. A round hole, allowing air to pass into the jar, is cut in the center of the circular wooden top and is covered with wire netting. As *sycophanta* is a climbing species, but is unable to make its way up the smooth sides of the jars, a narrow strip of mosquito wire is attached to the inside of the top, so that it extends into the jar and gives the beetle an opportunity to climb to the top in search of caterpillars that are placed in the jar for food. About 3 inches of loam should be placed in each jar, and they are then ready for use.

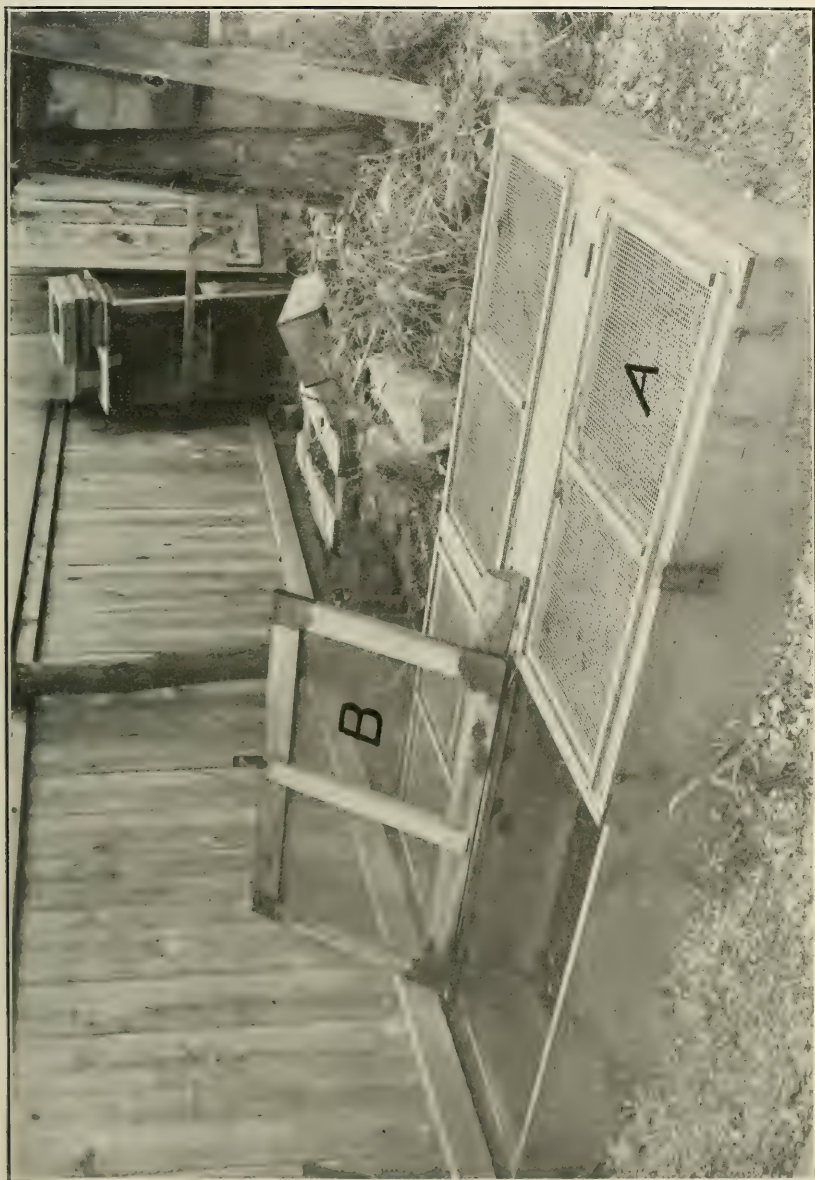
For rearing small larvæ of this species jelly tumblers containing earth and covered with cheesecloth can be used. The insects in this stage are cannibalistic, and it is therefore necessary to keep each larva in a separate jar if exact records are desired. Caterpillars or pupæ of almost any insect can be furnished for food and the soil must be kept slightly moist, but not wet. These larvæ can be reared



OUT-DOOR INSECTARIES FOR REARING CALOSOMA BEETLES.
A was built in 1909; B was built in 1910. (From Burgess.)



INTERIOR VIEW OF INSECTARY "B," SHOWN IN PLATE II. (FROM BURGESS.)



BOX CAGES USED FOR REARING CALOSOMA LARVÆ LATE IN THE SUMMER.

B, cover with fine-mesh screen, used in summer; A, showing coarse-mesh screen top, used after the larvæ have gone into the ground to transform and hibernate. (From Burgess.)

in wire cages if desired. The bottoms should be made of a circular piece of board $\frac{1}{4}$ inches in diameter, having a hole in the center covered with netting. To the circumference of this base is tacked a strip of wire netting 10 inches in width. It should be cut long enough to lap at the side, so that it can be sewed with wire. The selvage edge of the wire netting should be used for the top of the cage and care should be taken that the circumference at the top and the bottom are the same. A cover similar to the ones used on the glass jars may then be placed on the top of the cage. These cages should be set 8 inches in the ground. After the larvæ become full grown they descend into the ground and form their pupal chambers. Cages of this

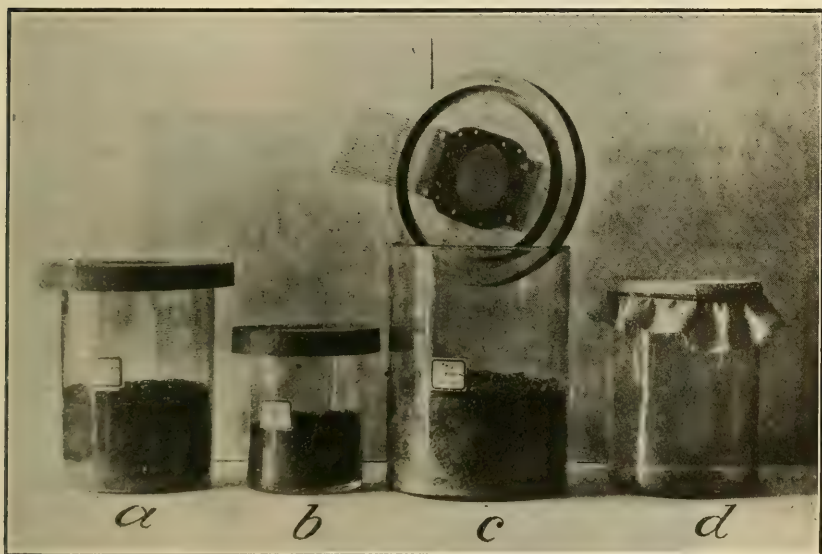


FIG. 2.—Jars for rearing *Calosoma* beetles: *a*, Large jar with wooden top and "ladder"; *b*, small jar with wooden top; *c*, showing construction of top and "ladder"; *d*, jar with cheesecloth top held in position with rubber band. (From Burgess.)

sort should not be disturbed until the following spring. For hibernating quarters for beetles, boxes with bottoms made of wire screen can be used (Pl. IV). They should be sunk into the ground from 18 to 20 inches, the earth inside the box being the same level as that on the outside. A hinged cover provided with wire netting should be placed on the top of the box and if convenient this cover should be padlocked so that the contents of the box will not be disturbed. Beetles may be placed in hibernation in cylinders (fig. 3) made of galvanized iron wire having a $\frac{1}{4}$ -inch mesh. These can be constructed in the same manner as the small cylinders already mentioned. If larvæ are to be placed in these cylinders it will be necessary to line them with fine wire screen in order to prevent their escape. This

equipment has been selected as a result of many experiments and has been found to work very satisfactorily.

METHODS OF REARING CALOSOMA BEETLE.

The most satisfactory manner of rearing these insects, in case it is desired to secure definite records of the number of eggs laid by a single individual or the amount of food consumed, is to place a pair

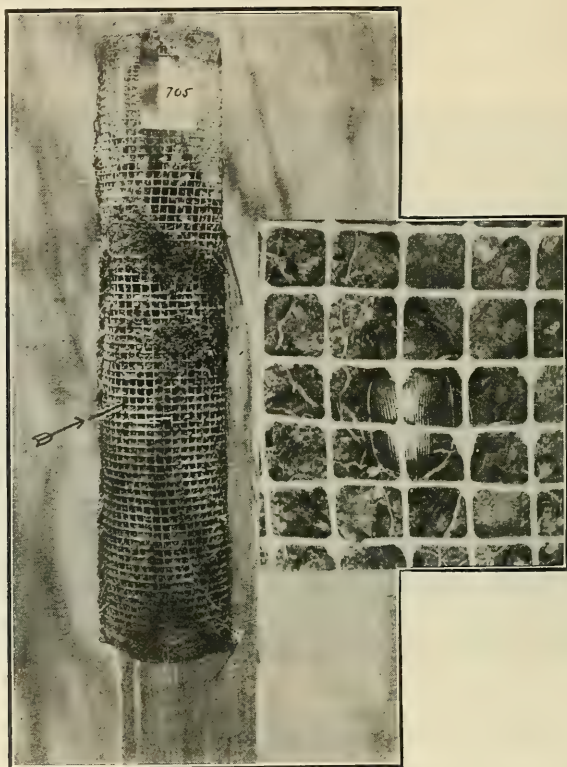


FIG. 3.—Wire hibernation cage that has been removed from the earth. Arrow shows the cavity where a *Calosoma* beetle hibernated; enlargement shows this beetle in the cage. (From Burgess.)

of beetles in one of the larger glass jars with a supply of caterpillars for food. The jars should be cleaned daily and all wounded or dead caterpillars removed. If this is not done, considerable difficulty is likely to be experienced. The earth should be examined daily, and if eggs are found the beetles should be transferred to a fresh jar and the original one kept, so that a record can be made of the larvæ that hatch. The number of larvæ that hatch is taken as an index of the number of eggs deposited, since it is impracticable to remove the eggs from the earth to make an accurate count, as they are easily

injured in handling. Records of the time spent in the different larval stages or the amount of food consumed may be secured by feeding the newly hatched larvæ in individual jelly glasses, as has already been described. When the larvæ become nearly full-grown they should be transferred to a larger jar, and it is better to place them in a wire cage sunk in the ground, so that they may have an opportunity to pupate in the soil without being disturbed.

These methods of rearing beetles were followed out, and in the spring and summer of 1908 and 1909 nearly 15,000 larvæ were reared and colonized in the field. Since that time it has been possible to collect both beetles and larvæ in the field, and the laboratory rearings for colonization have been discontinued.

LIFE HISTORY OF CALOSOMA SYCOPHANTA.

Contrary to general belief, the adults of this species live two or three years and sometimes four. This information has been secured by careful study of the habits of the insect carried out over a long period.

THE EGG (PL. I).

The egg is about 5.2 mm. long and 2.4 mm. wide, elliptical, tapering somewhat toward one end. It is white, with a faint yellowish tinge. The eggs are deposited in the ground by the females and hatch in from 3 to 10 days, depending upon the temperature. Careful experiments show that the time spent in the egg stage averages about 5.2 days in June and 4.4 days in July. Experiments have been tried to see whether or not hatching could be retarded by placing eggs in cold storage. In cases where they were exposed to freezing temperatures they shriveled and no hatching resulted.

THE LARVA (PL. I).

The larvæ on hatching are nearly white. They remain in the cavity occupied by the egg and gradually grow darker until they become jet black. They then make their way to the surface of the ground and begin searching for food. They attack caterpillars or pupæ with little regard to the size, cut through the body wall of their prey with their sharp mandibles, and feed on the liquids and soft tissues within. They molt twice before becoming full grown. These larvæ climb trees that are provided with rough bark and search for caterpillars or pupæ concealed in crevices. Molting frequently takes place on the tree trunk, so that the cast skins of the larvæ are frequently found on trees where they have been feeding. The full-grown larvæ average about 25.8 mm. in length and 5.7 mm. in width. The body is shining black, while the mandibles, legs, mouth-parts, antennæ, and lateral and ventral abdominal markings are

dark brown; the dorsum of the last abdominal segment is chestnut-brown. The two caudal appendages forming a part of the last abdominal segment are short and quite erect, and are provided with a large, stout, dorsal tooth and a smaller lateral tooth, both of which bear spines. Length of time in the larval stage varies with the temperature and food supply. The following record of 12 larvæ which hatched June 20, 1908, shows the time spent in active feeding:

	Days.
First larval stage-----	2
Second larval stage-----	3
Third larval stage-----	9
Total-----	14

The weather during this period was warm and the food supply was ample. The time when larvæ are found in the field is governed largely by weather conditions in the spring, but ranges from June 25 to the middle of August.

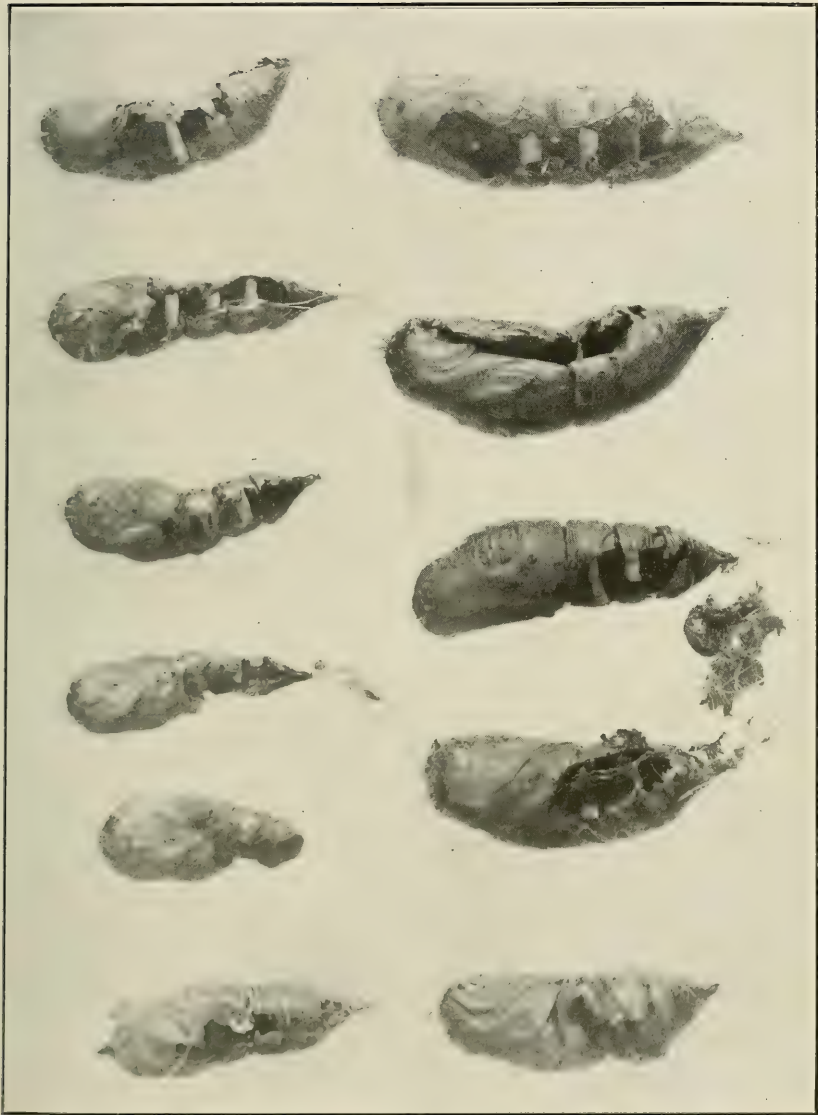
DISTANCE TRAVELED BY LARVÆ.

As has already been stated, the larvæ of the species are capable of climbing trees, and this makes it possible for them to feed on caterpillars or pupæ that may be present on the trunks or large branches. In some cases molted skins of the larvæ have been found in large trees at a height of 50 feet above the ground.

An experiment was carried on in 1910 to determine the distance that a newly hatched larva would travel if no food was supplied. The experiment started at 8.30 a. m., July 13, and continued uninterruptedly for 72 hours. Apparatus was constructed to measure accurately the distance traveled by this individual, which totaled 9,058 feet, or 1.78 miles. The weather was very hot during the time the experiment was carried on, and neither moisture nor food was supplied.

FEEDING HABITS OF LARVÆ.

The larvæ feed both by day and by night, and are more active when the weather is hot. As a rule, caterpillars are attacked from the side or from beneath, and if the specimens are hairy the favored place seems to be between the segments, where the larvæ can more readily pierce the integument with their sharp mandibles. Newly hatched *sycophanta* larvæ are able successfully to combat practically all caterpillars, regardless of size. Many specimens are injured to such an extent that they evidently die, and thus more caterpillars are prevented from transforming than are actually eaten. The pupæ of lepidopterons, especially those that are not provided with a cocoon, are particularly susceptible to attack by the *Calosoma* larvæ.



PUPÆ OF THE GIPSY MOTH THAT HAVE BEEN DESTROYED BY THE LARVÆ OF CALOSOMA SYCOPHANTA.
Note the irregular holes, which are characteristic. (From Burgess.)



LARVÆ OF *CALOSOMA SYCOPHANTA* FEEDING ON GIPSY MOTH CATERPILLARS UNDER BURLAP.

Photograph taken at Pine Bank Park, Malden, Mass., 1910. (From Burgess.)

The larvæ usually cut a hole between the segments of the pupæ (Pl. V), and after feeding begins the hole is gradually enlarged until the front portion of the body finds entrance to the pupa. The internal contents in most cases is completely devoured before the larva leaves the pupa to search for other food. The holes are always irregular in outline and can be easily distinguished from the exit holes of parasites. Gipsy-moth pupæ massed on the trunks of trees, underneath branches, or below burlap bands (Pl. VI) are favored locations as feeding grounds for *Calosoma* larvæ. In many towns in the infested gipsy-moth district one or more *Calosoma* larvæ can usually be found in each mass of gipsy-moth pupæ examined. These predaceous larvæ occasionally attack female moths, and several cases have been noted where the latter have been killed before they had an opportunity to deposit eggs.

Sycophanta larvæ feed freely on any lepidopterous larvæ or pupæ which they may find. A considerable number of cases have been noted where the larvæ have cut through the cocoons of the American tent caterpillar (*Malacosoma americana* Fab.) and forest tent caterpillar (*Malacosoma disstria* Hüb.) and have destroyed the pupæ within.

The life history of the *Calosoma* beetle is well adapted to that of the gipsy moth. The beetles are present and active during the time of year when gipsy-moth caterpillars are abundant and the larvæ are active and feeding while the gipsy moth is still in the pupal stage. No other common lepidopterous species which occurs in New England is so well adapted as a host of this beetle as the gipsy moth, and although large numbers of other caterpillars and pupæ are destroyed annually, the increase of the beetle is not as satisfactory in regions where the gipsy moth is not available for food.

In the summer of 1908 several series of experiments were conducted to determine the number of sixth-stage gipsy-moth caterpillars destroyed by the larvæ of *C. sycophanta*. It was found that on the average a single larva of this beetle would kill 41 full-grown caterpillars between the time of hatching and pupation. If smaller larvæ were attacked, a greater number would, of course, be destroyed. It is safe to say that 50 or more caterpillars would be necessary to satisfy the appetite of a *Calosoma* larva under field conditions. Most of the *sycophanta* larvæ hatch at a time when more gipsy-moth pupæ than caterpillars are available for food. Experiments show that on the average about 13 female pupæ are destroyed by each larva when fed in captivity. Observations in the field and jar experiments both indicate that a greater percentage of females than males is destroyed by the *Calosoma* larvæ, the average ratio being 75 per cent females to 50 per cent males.

EFFECT OF "WILT" ON CALOSOMA LARVÆ.

In the area infested by the gipsy moth a disease known as "wilt" is quite prevalent among caterpillars. A number of experiments have been conducted to determine whether *sycophanta* larvæ, if they were obliged to feed on caterpillars affected by this disease, would contract it and die. The experiments were conducted in 1910 and *sycophanta* larvæ were fed on diseased caterpillars in breeding jars. The results showed that the larvæ of this beetle suffer little if any from wilt. A few died, but no greater number than was the case in check experiments where healthy food was supplied. Only a single case has been noted in the field where *Calosoma* larvæ had apparently died from wilt, and as the specimens were not examined microscopically, death may not have been due to this cause. Beetle larvæ are so commonly found in masses of gipsy-moth pupæ and caterpillars which are dead or dying from wilt that if the beetle larvæ were susceptible to it, large numbers of dead specimens would be found.

EFFECT OF SPRAYING ON CALOSOMA LARVÆ.

The question has been repeatedly asked whether or not the spraying of infested areas would result in destroying the beetles or their larvæ on account of the belief that many of them would feed on poisoned caterpillars. Laboratory experiments, where caterpillars were taken from sprayed trees and used as food for beetle larvæ, show that the death rate was no greater than normal, while observations in the field have failed to reveal any case where the beetles or larvæ fed upon dead caterpillars or those in a dying condition from feeding on poisoned foliage. Apparently the beetles migrate in the field to locations where food is abundant. If eggs have been deposited in sprayed areas so that larvæ are abundant, little doubt remains that some of them may fail to secure food and die from starvation. No direct evidence is available to indicate that either the beetle or the larva is killed as a result of spraying, and we have always recommended that spraying should not be discontinued in cases of gross infestation in order to protect the beetles. The enormous increase of *Calosoma* seems to indicate that a discontinuance of spraying is not necessary.

STARVATION EXPERIMENTS WITH CALOSOMA LARVÆ.

Inasmuch as the ability of *Calosoma* larvæ to develop depends upon whether sufficient food can be found, a series of experiments was carried on in 1908 to determine how long they would survive in the different stages if no food was supplied. The larvæ were placed in jars containing a small amount of earth and no food was furnished.

The results showed that first-stage larvæ would live 3.56 days, second stage 6 to 9 days, and third stage 8 to 16 days before dying from starvation. This information, together with data secured on the distance which first-stage larvæ can crawl, indicates that the species is able to withstand adverse conditions and still survive.

PUPATION OF CALOSOMA LARVÆ.

Several attempts have been made to induce the larvæ to hibernate during the winter. A number of lots were placed in cold storage and several other experiments were conducted by placing the larvæ in jars of earth in a cold cellar. In every case, however, either the larvæ had transformed to pupæ, which had died, or to adults, when the jars were examined in the spring. After becoming full grown the larvæ entered the ground, formed a chamber, and entered the pupal stage. The depth to which the larvæ descend depends upon the condition of the soil. Occasionally pupæ of this beetle are found beneath boards or rocks, but in many cases they descend from 6 to 10 inches in loose soil before making the pupal chamber. In any event, pupation takes place above the frost line. After burrowing into the ground and forming a pupal chamber the body of the larva shortens, and after resting it transforms to pupa. The period from the time the larva stops feeding until pupation occurs averages about 10 days.

THE PUPA (PL. I).

The pupa of *Calosoma sycophanta* is pale yellow, about 25 mm. long and 12 mm. in width at the first abdominal segment. The mouthparts, antennæ, wings, and legs are folded beneath the head, the hind legs extending to the tip of the abdomen and the wings extending beyond the fourth abdominal segment.

Many experiments have been conducted in removing pupæ of this species from the cavities in which they pupated, but in most cases it is impossible to do this without causing injury and preventing normal emergence of the adult. In rearing this beetle care should be taken not to disturb the larva after it begins to form its pupal chamber, otherwise either a poor emergence of beetles or a considerable number of crippled specimens is likely to result. If definite records are desired regarding individual specimens, the larvæ should be allowed to pupate in wire cages in the ground. In case it is desired to rear through a large number of specimens without reference to definite records, a large number of larvæ can be placed periodically in one of the box cages previously mentioned. The time spent in the pupal stage averages about 13 days, and after the adults emerge they remain in the cavity which held the pupæ throughout the winter and do not ordinarily come to the surface of the ground until June 1

of the following spring. Many experiments have been tried in an attempt to force early emergence and with an idea of breeding this species during the winter in the laboratory, in order to increase the supply for liberation in the field. Efforts along this line have been futile. The species seems to have a well-fixed habit of winter hibernation, and apparently requires a long resting period. It is difficult to secure proper food for beetles that may be taken from hibernation during the winter, but, even if this could be obtained, no satisfactory way has been found to increase the number of broods annually.

THE ADULT OR BEETLE.

As has been previously stated, the beetles emerge about the first of June. The exact time varies slightly from year to year, depending upon the weather conditions. Beetle larvæ that transformed to pupæ and remained as beetles in the pupal cavities during the winter emerge at this time as well as other beetles that developed from larvæ in previous years. In July after the adults have finished feeding they burrow into the ground and form a cavity in which they remain the next winter. The distance beneath the surface varies greatly and depends to some extent on the looseness of the soil which they enter. They seldom go below the frost line, and, this being the case, the earth around them is usually frozen solid during the winter. The males and females enter hibernation about the same time, but the former usually emerge a day or two earlier in the spring. A few cases are on record where beetles have remained dormant in the ground continuously for nearly two years. In one instance a pair of beetles entered hibernation on July 28, 1910, and did not emerge from the ground until June, 1912. Several cases of this sort have been found as a result of careful notes from breeding experiments kept at the laboratory. In every case where this has occurred the beetles concerned were more than a year old. In no case have beetles failed to emerge the spring following their development from the larvæ. In connection with the hibernation of this species, it should be said that the beetles habitually live in that stage more than one year. As a rule they live for two years and several records indicate that it is not uncommon for them to remain in the beetle stage for three years. A record of one experiment shows that several females lived more than four years. Records kept at the laboratory indicate that the percentage of mortality during hibernation is rather high. It should be remembered that these beetles were placed in hibernating cages in the laboratory yard, and although here natural conditions are approximated as nearly as is possible, the location was not quite as suitable as if the insects had had an opportunity to make their own selection. In our experiments

the mortality of beetles during the winter runs from 22 to 35 per cent, first-year beetles showing the lowest death rate.

A large number of experiments were carried on in the spring of 1908 to determine whether it would be possible to induce this species to develop more than one brood in a single year. Beetles were removed from hibernation on March 4 and were fed in jars at the laboratory. Difficulty was experienced in securing a sufficient food supply, but the beetles did not feed at all freely and were rather inactive in the jars. Eggs were deposited a little earlier in the season than was the case when the species emerged normally, but the larvæ grew very slowly and did not develop much earlier than those which resulted from beetles that emerged early in June. The experiment indicated very conclusively that it was not possible to force this species and that the habit of developing a single generation a year is firmly fixed.

FEEDING HABITS OF ADULTS.

The beetles climb trees readily and travel out on the branches and sometimes cling to the leaves while searching for caterpillars. If disturbed they usually fall to the ground and immediately seek shelter underneath leaves or rubbish. The beetles usually seize the caterpillars in the middle of the back and cut through the body wall with their sharp mandibles. They feed upon the liquids and fatty material which form the body content of the caterpillar and usually injure many more than they actually devour. The average length of time during which the beetles feed is from about June 1 to July 15. From records secured in 1910 the shortest period of feeding was 32 days and the longest 66 days, with an average of 50 days. These records were secured from beetles kept in captivity. It will be noted that the time when the beetles are feeding corresponds roughly with the time when the gipsy moth is in the larval stage. This makes this beetle particularly adapted for feeding on the gipsy moth, and a further advantage results from the fact that the larvæ of *Calosoma sycophanta* are most active during the time the gipsy moth is in the pupal stage. The food of the adults is very similar to that of the larvæ; both are frequently found in the field feeding upon larvæ and pupæ of native Lepidoptera.

It is difficult to determine the number of caterpillars which are destroyed by a single beetle. This can only be done by feeding the beetles in captivity; and under these conditions they evidently do not destroy as many caterpillars as they would if they were living in the open. Experiments which have been conducted, using full-grown tent caterpillars and gipsy-moth caterpillars, showed that the average number of caterpillars destroyed by an old beetle was 328 and by young beetles 239. The young beetles—that is, those that are feeding

for the first year—do not eat nearly as many caterpillars as beetles that are older. On the other hand, the younger beetles seldom deposit eggs, while the older ones are very prolific.

Experiments conducted with small brown-tail moth caterpillars indicate that a much larger number of this species was destroyed. This is undoubtedly due to the small size of the caterpillars, and similar results would probably be secured if small gipsy-moth caterpillars were used for food.

In some of the laboratory experiments beef was offered to the beetles for food. They fed upon it to some extent for a short time, but after a week they refused to eat. Apparently they do not care for this substance if caterpillars are available.

EXPERIMENTS IN FEEDING BEETLES ON CATERPILLARS INFECTED BY WILT.

Several experiments have been conducted in feeding *sycophanta* beetles upon gipsy-moth caterpillars infected with the bacterial disease known as "wilt." Experiments were started in July, 1907, a single pair of beetles being fed from July 23 to August 14 with caterpillars which showed pronounced symptoms of the disease. Twenty-one larvæ were eaten, three were so badly injured that they died, and the remaining larvæ supplied to the beetles in the jar died from disease. These beetles ate slightly less than another pair that were fed on healthy caterpillars. Both pairs entered hibernation and those that were furnished diseased caterpillars showed no ill effects. Several similar experiments have been conducted since that time, and the results indicate that these beetles are not susceptible to the "wilt." Each year large numbers of gipsy-moth caterpillars die from the disease in jars where *Calosoma* beetles are confined for experiments, and if it was seriously destructive to the beetles or their larvæ the fact would have been determined by heavy mortality among them.

EFFECT OF SPRAYING ON BEETLES.

Several attempts have been made to determine whether *Calosoma* beetles are injured or killed by feeding on gipsy-moth caterpillars taken from sprayed trees. In 1910 a small area of brush growth near the laboratory was sprayed with arsenate of lead, and gipsy-moth caterpillars collected from time to time were furnished the beetles for food. Check experiments were also run in unsprayed areas. The experiment failed to show that any of the beetles were injured by feeding on caterpillars taken from sprayed foliage. Several colonies of beetles have been liberated in woodland that has been heavily sprayed, and not infrequently beetles are found on street or park trees which have been sprayed with arsenate of lead. Dead beetles or their larvæ are found very rarely, and thus it is evident

that no wholesale injury to the species is caused by their feeding on poisoned caterpillars.

STARVATION EXPERIMENTS.

In 1910 experiments were conducted to determine the length of time that these beetles could survive without food. For this purpose two pairs of young beetles and two pairs of old beetles were placed in jars of earth in one of the cages in the laboratory yard. The results of the experiment are shown in Table II:

TABLE II.—*Starvation experiment to determine the length of time adult Calosoma sycophanta can live without food.*

<i>Calosoma sycophanta.</i>	Date emerged from hibernation.	Date male died.	Length of time male lived without food.	Date female died.	Length of time female lived without food.
	1910.	1910.		1910.	
Young pair.....	May 26	June 26	1 month.....	July 9	1 month 13 days.
Do.....	do.....	June 29	1 month 3 days....	July 5	1 month 9 days.
Old pair.....	do.....	July 17	1 month 21 days....	June 26	1 month.
Do.....	do.....	June 30	1 month 4 days....	(¹)	1 month 21 days. ¹

¹ This female, after living without food for 1 month and 21 days, was offered several full-grown gipsy-moth caterpillars July 17 and ate two in 10 minutes. The next day a male was added and copulation was attempted several times, but without satisfactory results. The female died July 30 without depositing eggs. During the 12 days the pair were in the jar 33 sixth-stage gipsy-moth caterpillars were eaten.

This experiment shows that beetles of this species can live during the summer for a month or more without food. Old beetles appear to withstand starvation better than young beetles, and males die sooner than females. In 1907 a field colony of beetles was liberated in order to test their ability to survive where the food supply was very limited. Fifty specimens, 25 of each sex, were liberated in woodland at Peabody, Mass., August 28. The beetles were received from Europe early in the month and had been supplied with very little food after their arrival. At the time they were liberated there were no gipsy-moth caterpillars in the field and very few pupæ. An occasional native caterpillar could be found, but they were rare in the vicinity of the colony. Several examinations were made the following spring and summer. On July 8 *Calosoma* larvæ were found, showing that the species had survived and that reproduction had taken place. This indicates that the beetles are able to survive under very unfavorable conditions.

In order to determine how far male beetles might be attracted by females, several experiments were conducted, but negative results were secured.

REPRODUCTION.

After emerging from hibernation and feeding for a few days, copulation takes place and eggs are deposited by the females. It is neces-

sary for the latter to mate several times during the season, or a large percentage of infertile eggs will be laid. Old beetles lay many more eggs than young beetles. The highest number of eggs laid by a single female in a season was 653. If an average is taken covering all the beetles under observation for a single year, both young and old, the rate of increase—that is, the average number of eggs deposited by each female—will be about 100. The result of several years' work in rearing beetles in confinement indicates that it is a common habit of this species to oviposit sparingly, if at all, the first summer, and to lay eggs freely the second season. If conditions are favorable the first year, a number of eggs may be laid, while if they are unfavorable oviposition is postponed until the second or third summer, as the case may be. It sometimes happens that eggs are laid the first and third summers, but not during the second; at any rate, each female will lay about an equal number of eggs, but the time they are deposited varies greatly.

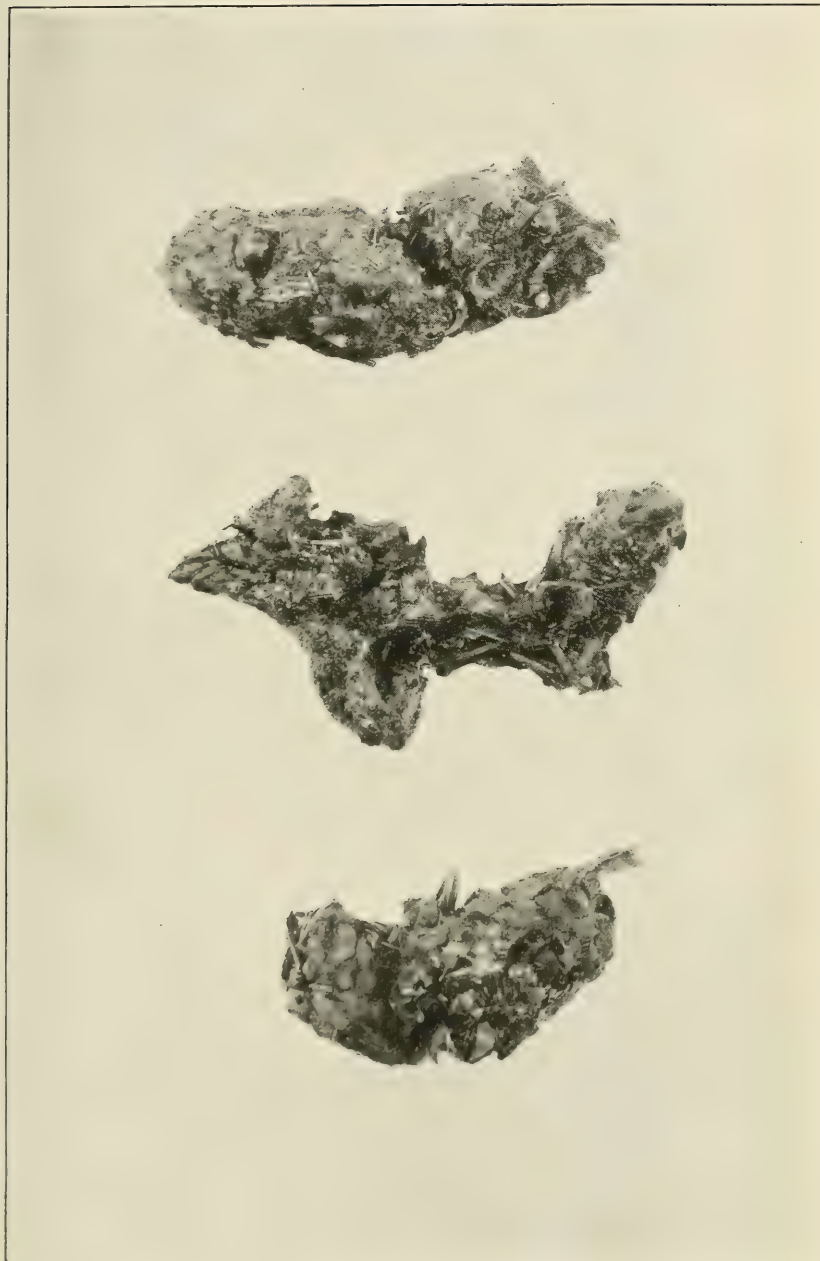
The data secured from field colonies indicates that the same conditions apply. Two-thirds of the localities that were colonized with beetle larvæ have shown some reproduction the year following planting, while colonies where adults were liberated usually show much larger increase. The jar records indicate that the old beetles multiply seven times as fast as the young ones, and in the field, based on the number of molt skins found in several colonies, the average is 10 to 1 in favor of the old beetles.

HABITS OF FLIGHT.

For a number of years it was believed that these beetles did not fly. They were frequently seen in trees, and when disturbed would fall to the ground without making any effort to use their wings. A number of observations, however, prove that the species flies quite freely, particularly early in the spring. There is at that time considerable migration of the adults after they emerge from hibernation; and they undoubtedly seek localities where food is plentiful. The fact that beetles have been found more than 20 miles outside the area where they were colonized indicates that spread is accomplished by flying or that the species was carried on vehicles or in some other way.

ATTRACTION OF ADULTS TO LIGHT.

Several native species of *Calosoma* are attracted to strong light. Although many observations have been made in eastern Massachusetts, where *sycophanta* was first colonized, and where the species is abundant, it has never been taken at arc lights, and we have received no record to that effect from various collectors in this vicinity. Several specimens are reported to have been taken at electric lights



EXCREMENT OF SKUNK COLLECTED IN THE FIELD, SHOWING MANY FRAGMENTS OF ADULTS OF *CALOSOMA SYCOPHANTA*. (ORIGINAL.)

at Salisbury Beach, Salisbury, Mass., in 1913. It is probable that the species is occasionally attracted to lights, but it is apparent that this beetle does not frequent lights as commonly as other species of the same genus.

EXPERIMENTS IN DROWNING BEETLES.

Early in the spring of 1910 a number of experiments were conducted to determine whether beetles could continue to live after being submerged in water for any length of time. This information was quite desirable, inasmuch as areas where the beetles hibernate during the winter might in the spring be covered with water for a considerable period, so that unless the species are able to withstand submergence many specimens might be destroyed in this way.

March 17, 1910, cages containing frozen earth were dug up and two male beetles were removed from their cavities and put in a jar of water. At 11 a. m. the jar was placed in the laboratory ice chest and kept at a temperature of 39° F. Some pieces of cloth and two small blocks of wood were put in the jar with the intention of keeping the beetles submerged, but at 5.58 p. m., when an examination was made, both beetles were found swimming about in the water. They were again submerged by placing a quantity of blotting paper inside of the jar, but on the following morning they had succeeded in making their way to the surface. A wooden float was then constructed which was placed in the jar in such a manner as to keep the insects under water. They were kept in this position four days, although every 12 hours they were taken out and examined to see if they showed signs of life. At the end of this period they were removed, apparently dead, but in less than an hour they revived sufficiently to begin feeding on cutworms.

This experiment shows that beetles of this species can live for at least four days, and probably longer, if submerged in water a few degrees above the freezing point.

March 17, 1910, several small wire cages, used for feeding larvæ, each of which contained a newly formed beetle, were dug up and submerged in a tub of water to see if the insects would survive this treatment. There were several inches of frost on the top of each cage and the temperature of the water was about 39° F. March 18, at 8 a. m., one female had emerged and was clinging to the wire just above the water. An examination of the earth in this cage showed that the hibernation cavity was about 6 inches deep, and as soon as it thawed out the insect made its way to the surface of the water.

Another cage was examined after it had been submerged 24 hours and a living beetle was found 3½ inches below the surface of the earth. The cage was replaced and removed later in the day and it was found that the beetle had worked its way to a point a half inch

below the surface of the earth. It appeared dead, but on removal soon revived.

At the end of 48 hours another cage was examined, and a live beetle found $3\frac{1}{2}$ inches below the surface of the earth. This cage was replaced and on the following morning, after it had been submerged for $2\frac{1}{2}$ days, the beetle was found on the surface of the water.

The last cage was opened at the end of four days, and an active female was found in the earth, which was now very compact. The beetle was replaced in the mud and the cage submerged, but at 3.10 p. m. it came to the surface of the water, after having remained beneath it four days and two hours.

These experiments indicate that this species is able to withstand excessive amounts of moisture and that in the spring, when lowlands are flooded, the majority of the insects will survive, apparently without serious inconvenience.

On March 21 a female *Calosoma* beetle that had been submerged for four days and two hours was placed in a tub of water and floated about on the surface. It seemed desirable to ascertain how long the insect would remain alive and float when the temperature of the water was maintained at about 39° F., and also whether it was able to make any progress in swimming. During the first hour and fifteen minutes the insect swam a distance of 22 inches. It rested on the water very easily, less than one-half of the body being submerged. The legs moved continually, but its progress was very slow. This beetle remained in the tub of water 15 days and at the end of that period was removed for dead. In a few hours it revived and began feeding, and was used later in the summer in rearing experiments. This shows that in the spring beetles of this species might survive several days if they should fall into ponds, and that they would probably float with the current and might be distributed quite a long distance in this way, especially if they fell into streams or rivers.

NATURAL ENEMIES.

It is undoubtedly true that this species is eaten to some extent by birds, and the hairy woodpecker has been charged with destroying it on several occasions. The crow has been observed to feed on the beetles and also to carry them to their nests which were occupied by young birds. Among the other vertebrate enemies may be mentioned skunks, raccoons, and foxes. The last two mentioned, when kept in captivity, will feed on these beetles very freely. Abundant evidence has been secured that skunks destroy large numbers of the beetles. In some sections where these insects were very abundant it was found that the remains of the beetles formed the chief constituent of the excrement of this animal. (Pl. VII.) Not only do the skunks secure beetles which may be on the ground, but they

undoubtedly obtain many that have just transformed to the beetle stage and are just beneath the surface. In several places, where beetles were numerous and were doing good work in destroying gipsy-moth caterpillars, it was found later in the season that the ground beneath the trees had been uprooted to a considerable extent and skunk droppings containing large numbers of beetle remains were abundant in the locality.

These beetles are also attacked by a tachinid fly, probably *Viriania georgiae*, as a few specimens of this species have been reared from beetles which died after they had been brought in from the field.

Under laboratory conditions the beetles and their larvæ are sometimes seriously attacked by a mite known as *Tyroglyphus armipes* Bks. It is improbable that they suffer from this enemy under field conditions, but unless breeding jars are kept free from dead caterpillars, considerable difficulty is likely to result in rearing the insect in confinement.

COLONIZATION OF CALOSOMA SYCOPHANTA.

Colonies of this species were first liberated in the field in 1906 in the towns of Saugus, Malden, Winchester, Burlington, and Lynnfield, Mass. Other colonies have been released since that time in territory where the insect did not occur and where gipsy-moth infestation was severe. There have been liberated in the field about 2,700 beetles which were imported from Europe; in addition to this, during the first two or three years following 1907, colonies of larvæ and some beetles reared at the laboratory were also released in the field. Since 1910 this species has not been received from Europe, and most of the specimens colonized have been collected in eastern Massachusetts, where the beetles have become abundant. Table III gives a summary of the number of beetles imported, as well as those collected and colonized since the work began.

TABLE III.—Number of living *Calosoma sycophanta* imported, and number of beetles and larvæ colonized.

Year.	Received.	Colonized from importations.	Colonized from rearings and field collections.	
			Adults.	Larvæ.
1906.....	633	389	.....	.....
1907.....	967	578	.....	.....
1908.....	675	430	.....	2,300
1909.....	405	250	.....	6,100
1910.....	1,305	1,064	452	6,380
1911.....	.....	.....	621	1,104
1912.....	.....	.....	176	.....
1913.....	.....	.....	3,014	2,901
1914.....	.....	.....	4,244	330
Total.....	4,045	2,711	8,507	19,115

In addition to the beetles colonized, as given in Table III, 340 living specimens were shipped from the laboratory during 1912 and 1913. Most of these went to New Brunswick, Canada, where an infestation of the brown-tail moth exists, but a small lot was shipped to the commissioner of horticulture of California for colonization in that State, and another lot was forwarded to New Mexico, where a serious outbreak of the range caterpillar (*Hemileuca oliviae* Ckll.) exists.

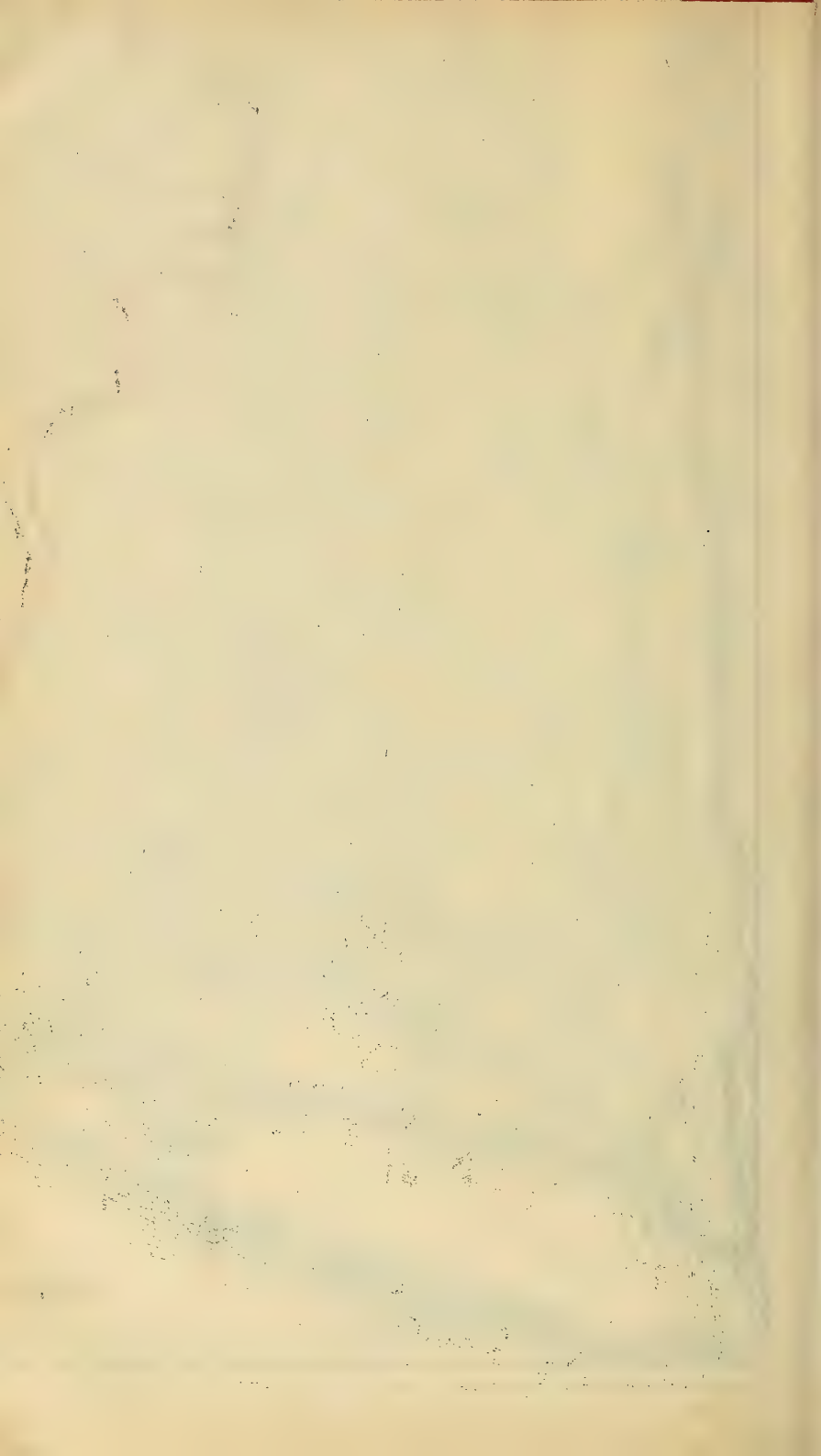
In 1914, 1,830 specimens were collected by Mr. L. S. McLaine, an assistant of Dr. C. Gordon Hewitt, entomologist to the Dominion of Canada, and shipped to New Brunswick, and 1,700 were obtained by Mr. H. E. Smith and forwarded to New Mexico by arrangement with Prof. F. M. Webster, in charge of cereal and forage insect investigations in the Bureau of Entomology.¹

METHODS OF SECURING DATA FROM FIELD COLONIES.

In order to determine whether this species has increased in spread under natural conditions, a large amount of work has been carried on each year in the field. Owing to the large size of the beetle and its larvæ, it is comparatively easy to make observations on this species. For the first few years after liberations were made observations were carried on in the localities where the colonies were planted. The work was taken up about the 1st of July and continued as long as information could be secured in August. Effort was made to determine not only whether the species had survived, but to find out whether it was spreading. This work gave very gratifying results. On trees which were burlapped it was possible in many cases to find the beetles or their larvæ feeding on gipsy-moth larvæ or pupæ beneath the bands. The beetle larvæ feed extensively on gipsy-moth pupæ, and it is quite easy to determine if pupæ have been destroyed by this means, even though the insect may not be present. As the larvæ of *sycophanta* climb trees and feed among masses of pupæ, an examination of these masses in midsummer usually indicates whether the species is present. An additional help in this respect results from the fact that these beetle larvæ molt among the masses of pupæ on the trees, and unless there are heavy rains, which wash these molted skins to the ground, it is possible, for a period of several weeks after actual feeding took place, to determine whether the species has been present. Using this information as a guide, parties of men have been employed each year to examine infested places in the towns outside of localities in which colonization actually took place. In this way it has been possible to determine the spread of the insect from year to year

¹ Results of the introduction into New Mexico will be set forth in detail in a report on the range caterpillar investigation of this bureau.





and to secure data on the abundance of the species and the effectiveness of its work.

The accompanying map (Pl. VIII) shows the territory infested with the gipsy moth in 1914; also the areas where the *Calosoma* beetle was found from the years 1910 to 1914, inclusive.

DISPERSION OF CALOSOMA SYCOPHANTA.

Table IV shows the annual dispersion of *Calosoma sycophanta* since it was introduced into Massachusetts. This information has been secured by careful field examinations, and towns have not been included in the area unless the beetles or their larvæ have been found in several localities throughout the town.

TABLE IV.—Table showing annual dispersion of *Calosoma sycophanta* in New England, 1909–1914.

Year.	Area.	Year.	Area.
	<i>Sq. m.</i>		<i>Sq. m.</i>
1909.....	9	1912.....	1,615
1910.....	106	1913.....	3,003
1911.....	425	1914.....	5,445

The statements which follow give a list of the towns and cities in Massachusetts, New Hampshire, Maine, Rhode Island, and Connecticut in which colonies of this species have been liberated, the number released, and the places where they have been found as a result of spread from nearby towns. The records are complete up to and including 1914, and the information is given somewhat in detail, so that it may be of value to owners of property or residents in the sections concerned.

MASSACHUSETTS.

Abington.—No colonies were liberated in this town. Examinations of woodlands in 1914 resulted in finding traces of the beetles, although little damage was noted by the gipsy moth.

Acton.—In 1910 a colony of 200 larvæ was liberated in the western part of the town. During August, 1912, the larval molt skins were found in many woodlands throughout, and further evidences of the increase and efficiency of the species were reported in 1913 and 1914.

Amesbury.—In 1910 a colony of 200 larvæ was liberated in woodland off Haverhill Street. August, 1912, examinations showed them to be present in many localities throughout the town, and in 1913 and 1914 further reports indicated that they had become numerous in these sections.

Andover.—During 1910, 100 beetles were liberated in this town. In 1911 they were recovered in a few localities. They were recovered in 26 different localities in 1912. Additional data secured in 1913 and 1914 showed them to be present in large numbers throughout. These records are indicative that these beetles are common enough throughout this section to be accomplishing an appreciable amount of good as an enemy of the gipsy moth.

Arlington.—In 1910, 200 beetle larvæ were colonized. During 1911 they were recovered in various localities. No further examinations have been made, as the results indicated that this species was well established here.

Ashburnham.—In 1914, 87 beetles were colonized in a section where there was a heavy infestation of gipsy moths. Later reports show that the beetles had spread sparingly into other sections.

Ashby.—During 1914, 174 beetles were liberated in two localities where gipsy moths were abundant. They also made their appearance in other sections as a result of spread from other towns.

Ashland.—A colony of 100 beetles were liberated in 1913 at a locality where the gipsy-moth infestation was moderate. Later in the season this species was recovered at points distant from the colony. In 1914 it was universal throughout the town.

Avon.—No colonies were liberated here, but in 1913 recoveries were made in the southern part of the town, and a satisfactory increase was noted in 1914.

Ayer.—In 1913 beetles were recovered in three localities, although no colonies had been liberated. This species showed remarkable increase in 1914.

Barnstable.—No beetles were liberated in this town. In 1914 this species was reported as abundant in various localities.

Barre.—No colonies were liberated, but beetles were reported in 1914, which is a result of spread from other towns.

Bedford.—During 1910, 100 beetles were liberated. In 1911 this species was recovered in localities surrounding the colony. Examination made in 1912 showed them to be present in 10 widely separated points throughout the town. In 1913 and 1914 the beetles were common in all sections.

Belmont.—During 1911 larval molt skins were found in a number of localities, although no liberations were made here. In 1912, 1913, and 1914 beetles were present in all the infested localities.

Berlin.—No colonies were liberated here, but in 1913 beetles were found in two localities. Reports in 1914 show this species to be quite abundant.

Beverly.—During 1909, 200 beetle larvæ were liberated off Essex Street. In 1910 beetles were recovered in points surrounding the colony. This species was found in many localities in 1911, and in 1912, 1913, and 1914 it had become well established.

Billerica.—In 1909, 100 beetles were liberated. Examinations in 1912 showed them to be present in most of the woodland areas. This species was very common in 1913 and 1914.

Bolton.—Although no colonies were liberated here, the beetles were found in three localities in 1913. Reports show this species to be abundant in 1914.

Boston.—During 1910, 200 beetle larvæ were liberated in the Hyde Park district. In 1911 they were recovered in the Jamaica Plain and West Roxbury sections. Inspections in 1912 showed them to be common in the Hyde Park, Jamaica Plain, and Dorchester sections; also in Franklin Park. They were reported very common and doing efficient work in woodlands where gipsy moths were present in 1913 and 1914.

Boxboro.—No colonies were liberated here. Larval molt skins were found in one locality in 1912. During 1913 this species was found in other parts of the town, and in 1914 it had become quite common.

Boxford.—In 1910, 200 beetle larvæ were liberated. During 1912 larval molt skins were found in 10 widely separated localities. Additional data secured in 1913 and 1914 showed them to be well established throughout the town.

Boylston.—Although no colonies were planted here, beetles were recovered in one locality in 1913. In 1914 this species was reported from many sections of the town.

Bradford.—In 1910, 200 beetle larvæ were liberated. During 1912 larval molt skins were found in one locality. Reports in 1913 and 1914 show them to be rather common throughout the town.

Braintree.—Two hundred beetle larvæ were liberated here in 1909. Examinations during 1910 showed them to be present at and near the colony. In 1912 beetles were found in three separated localities. They were reported quite common in 1913 and 1914.

Brockton.—No colonies were liberated here, but in 1913 beetles were found in the northern part of the city. Further notes in 1914 showed that the beetles had increased considerably.

Brookline.—During 1908, 145 beetles and 100 beetle larvæ were liberated. In 1909, 200 beetle larvæ were added to another infested woodland. Examinations in the summer of 1909 showed that the beetles had migrated somewhat. During 1910 they were reported as reproducing and spreading favorably. In 1911 they had spread into 20 different localities and since that time they have steadily increased and have become well established.

Burlington.—Forty beetles were liberated here in 1906. In 1907 and 1908 a few larval molt skins were found. During 1909 beetles were found three-fourths of a mile from the colony, and in 1910 they were noted a considerable distance from the center of the original colony. In 1911 and 1912 this species was reported common in all sections of the town. Later reports show them to have increased and become well established.

Canton.—During 1911, 100 beetles were liberated. In 1912 larval molt skins were found in the center of the colony and in five isolated localities of the town. Reports of 1913 and 1914 show this species to be present in large numbers and steadily increasing.

Carlisle.—In 1910, 100 beetles were liberated. A thorough inspection was made in 1912 and they were recovered in a number of different localities. Since that time they have steadily increased and become effective.

Carver.—During 1913, 85 beetles were liberated. In 1914 larval molt skins were found common in all parts of the town where gipsy moths were present.

Chelmsford.—One hundred beetles were liberated here in 1910 and during 1912 they were recovered in several localities. Reports made in 1913 and 1914 found them present in large numbers.

Clinton.—No beetles were liberated here, but examinations made in 1914 show them to be rather common in all parts of the town.

Cohasset.—In 1909, 400 beetle larvæ were released in this town. During 1912 they were recovered in several localities. Additional data secured in 1913 and 1914 show this species to be well established.

Concord.—Fifty beetles and 100 beetle larvæ were liberated here in 1908, and 400 larvæ in 1909. Examinations made in 1910 indicated that they had spread a considerable distance from where the colonies were liberated. In 1911 and 1912 this species was recovered in several sections and reports made in 1913 and 1914 show them to be abundant in all localities.

Danvers.—During 1909, 300 beetle larvæ were liberated, and in 1910 they were recovered a short distance from the colony. Examinations made in 1911 resulted in finding molt skins in numerous localities. Further evidence secured in 1913 and 1914 showed this species to be well established.

Bedham.—In 1910, 200 beetle larvæ and in 1911, 100 beetles were liberated. Beetles were present in most of the woodlands in 1912. In 1913 and 1914 they were found to have increased considerably and had become well established.

Dover.—Two hundred beetle larvæ were liberated here in 1910. In 1912 larval molt skins were found in five widely separated localities. Data received

in 1913 gave evidence that they were well established, and in 1914 they were found to be very abundant.

Dracut.—In 1910, 100 beetles were liberated. During 1912 they were recovered in various localities. In 1913 and 1914 the species was well established and very abundant in some localities.

Dunstable.—No colonies were liberated in this town, but in 1912 beetles were found in three widely separated sections. Reports of 1913 and 1914 show this species to be rather abundant in various localities.

Durbury.—Beetles were found in the northern part of this town in 1913, although none had been liberated. In 1914 examinations showed them to be present in all sections.

Easton.—In 1913, 100 beetles were liberated and reports in 1914 showed the beetles to have spread to other localities.

East Bridgewater.—No beetles were liberated here, but in 1914 they were found in localities where gipsy moths were present in sufficient numbers.

Essex.—In 1909, 549 beetle larvæ were liberated in three separated localities. Beetles were recovered at and near these colonies in 1910. During 1912 examinations showed them to be present in large numbers in all sections, and in 1913 and 1914 they were reported to be abundant in all gipsy-moth infestations.

Fall River.—No liberations were made here, but in 1914 Mr. Norman S. Easton, President of the Society of Natural History, reported finding an adult in the center of the city.

Fitchburg.—One hundred beetles were liberated in 1913 in the western part of the city. During 1914, 87 beetles were liberated on Ashburnham Hill Road and 87 near Burbank Hospital. Later reports show them to be present in nearly all of the wooded sections of the city.

Foxboro.—In 1913, 100 beetles were liberated in this town, and during 1914 they were recovered in three different localities.

Framingham.—Two hundred beetle larvæ were liberated in 1910 in the northeastern part of the town. During 1912 they were recovered in several locations in the eastern part and in 1913 the species was quite common in the western section. Further data secured in 1914 showed them to be quite abundant in all localities.

Franklin.—No beetles were liberated, but in 1914 larval molt skins were found in some sections of the town.

Georgetown.—In 1909, 200 beetle larvæ were liberated in the southern part of the town. They were recovered in and near the colony in 1910. During 1912 examinations showed them to be present in a number of localities, and they were reported to be abundant in 1913 and 1914.

Gloucester.—In 1908, 275 beetle larvæ were liberated in three localities of the town. Examinations in 1910 showed them to be present in localities some distance from the original colonies, while in 1911 they were recovered in several sections. They were reported abundant in a number of localities in 1913 and 1914.

Grafton.—90 beetles were liberated in the northern part of the town in 1914. Later in the season they were recovered in the northern and eastern sections.

Groton.—No colonies were liberated here, but examinations made in 1913 and additional data secured in 1914 indicated that the beetles were well distributed in all sections of the town.

Groveland.—In 1910, 200 beetle larvæ were liberated in the center of the town, and in 1913 they were recovered in several well-separated localities. Later reports show this species to be abundant in all sections.

Halifax.—Although no colonies were released in this town, beetles were found in nearly every locality examined in 1914.

Hamilton.—During 1909, 104 beetles and 100 beetle larvæ were colonized in this town. In 1912 they were found in several localities visited. Reports in 1913 and 1914 proved that this species was well distributed and quite abundant in some districts.

Hanover.—No beetles were liberated here, but a careful survey of the woodlands made in 1913 resulted in finding them in no less than nine well-distributed localities. Later reports indicate their increase and further spread.

Hanson.—While no colonies were liberated here, examinations in 1913 and reports made in 1914 showed them to be common in a number of localities where gipsy moths were in sufficient numbers.

Harvard.—No beetles were liberated in this town, but examinations made in woodlands infested by gipsy moths in 1913 gave proof that this species was present in nearly all localities. In 1914 they were reported quite common throughout.

Haverhill.—In 1910, 200 beetle larvæ were liberated in the southeastern part of the city. During 1912 they were recovered in several localities in the wooded sections. Later reports prove that this species is quite common in the areas infested by gipsy moths.

Hingham.—Eighty-three beetles were liberated here in 1912. Later in the year they were recovered in five different localities. In 1913 and 1914 they had become well established.

Holbrook.—No liberations were made in this town, but recoveries have been made in all the surrounding towns near the town line.

Holden.—In 1913, 190 beetle larvæ were liberated, and in 1914, 90 beetles were colonized off Princeton Road.

Holliston.—During 1913, 100 beetles were liberated in the central part of the town. They were recovered in one locality outside of the colony later in the year. As a result of examinations in 1914 it was found that this species had little chance of increase, as the gipsy-moth infestations were light.

Hopkinton.—One hundred beetles were liberated here in 1910. During 1913 they were recovered in one locality. No larval molt skins were found in 1914, the gipsy-moth infestation being very light.

Hudson.—In 1910, 100 beetles were liberated on Priest's Hill. Examinations in 1912 showed them to be present in a number of locations. In 1913 and 1914 this species had become quite abundant throughout the town.

Ipswich.—During 1909, 200 beetle larvæ were liberated in the northern part of the town. Larval molt skins were recovered in large numbers in some localities during 1912. Reports received in 1913 and 1914 show that the species had increased and was well established.

Kingston.—In 1912, 93 beetles were liberated here. They were recovered in four near-by localities in 1913, and scouting in 1914 showed them to be present in all parts of the town.

Lakeville.—No colonies were liberated here, but larval molt skins were found in the center of the town in 1914.

Lancaster.—No liberations were made here, but in 1912 beetles were noticed in a few localities. Reports in 1914 show them to be quite common in a number of sections.

Lawrence.—Two hundred beetle larvæ were liberated in South Lawrence in 1910. In 1911 they were not recovered, except in adjoining towns near the city line. During 1913 and 1914 they were reported in large numbers in all the wooded sections.

Leicester.—Although no beetles have been liberated here, they were reported as being present in the southern part of the town in 1914.

Lcominster.—In 1913, 200 beetle larvæ were liberated in the southeastern part of the town. From examinations made the same year they were found present in a few localities quite remote from the original colony, and in 1914 well distributed.

Lewington.—During 1908, 100 beetle larvæ were liberated off State Road, and in 1909, 200 larvæ were colonized in the eastern part of the town. A careful examination was made in all infested woodlands in 1912, and beetles were recovered in 40 different localities. Later reports prove that they are abundant and doing efficient work.

Lincoln.—In 1908, 100 beetle larvæ were liberated in the northwestern section. During 1910 they were recovered in localities somewhat remote from the colony. Examinations in 1911 and 1912 showed them to be present in all the localities infested by gipsy moths, and since that time their effective work has been very noticeable.

Littleton.—In 1910, 200 beetle larvæ were liberated a short distance from the railroad station. During 1912 examinations showed them to be quite common in some localities. Later they were reported abundant in most sections of the town.

Lowell.—During 1910, 200 beetle larvæ were liberated near the Lowell General Hospital. In 1912 they were recovered in five different localities. In 1913 and 1914 the species had increased and was doing efficient work in the woodland areas.

Lunenburg.—No colonies were liberated in this town, but in 1913 beetles were recovered in a few localities in the eastern part. During 1914 they had spread to all sections, and in one point near the center they had increased to such proportions that the adults and small larvæ destroyed about 49 per cent of the gipsy-moth caterpillars. As a result of counts made after the gipsy moths had reached the pupal stage it was found that about 78 per cent of the pupæ were destroyed by the beetle larvæ alone.

Lynn.—No colonies were liberated in this city, but colonies were planted in Lynnfield and Saugus near the Lynn Woods Reservation. In 1910 beetles were recovered in a number of localities in the reservation. Examinations in 1911 showed them to be well established in nearly all parts of this woodland. Since that year they have continued to increase and have assisted materially in lessening the damage done to these woodlands by the gipsy moths.

Lynnfield.—In 1906, 100 *C. sycophanta* and 20 *C. inquisitor* adults were liberated near Broadway. Later this same year 218 of the former species were colonized two miles distant. *C. sycophanta* was recovered in 1908 and 1909. From examinations in 1910 these beetles were found spread throughout the southern part of the town, and since that time they have increased in large numbers and are doing satisfactory work.

Malden.—During 1906, 40 beetles were liberated in the Maplewood section. They were recovered in a few localities in 1908 and 1909. This species from 1910 to 1914 was found to have spread to all sections and was doing very efficient work in destroying the gipsy moths.

Manchester.—In 1909, 73 beetles and 850 beetle larvæ were liberated in five localities of this town. Scouting in 1911 showed them to be present in and at a considerable distance from the colonies. In 1912 this species was found to be common in many of the woodland areas. During 1913 and 1914 they had become well established throughout.

Mansfield.—No beetles were liberated, but in 1914 larval molt skins were found in a few localities.

Marblehead.—In 1908, 200 beetle larvæ were liberated one-half mile east of Forest River station. They were recovered in small numbers in 1910. Examinations made in 1911 showed them to be present in and at some distance from the original colony. Later reports indicate that this species has increased to great numbers in some localities.

Marlboro.—No beetles were liberated in this town, but in 1912 larval molt skins were found in woodlands in the northeastern part. During 1913 they were found in the southern and western sections. Later reports show that this species is rather common in the wooded sections of the city.

Marshfield.—In 1910, 200 beetle larvæ were liberated near Marshfield Center. During 1913 several examinations were made, and larval molt skins were found in a number of widely separated localities. Later reports show them to be well established.

Mashpee.—Eighty-five beetles were liberated in 1913 in woodland north of Wakeby Pond and 316 beetle larvæ in woodland south of Johns Pond. As a result of scouting in 1914, it was found that this species had dispersed into most of the infested sections of the town.

Maynard.—In 1910, 200 beetle larvæ were liberated in badly infested woodland. Observations were made in 1912, and the species was recovered in and around the colony. In 1913 and 1914 the species had become well established throughout the town.

Medfield.—During 1910, 100 beetles were liberated in Rocky Woods. In 1912 larval molt skins were found in a few localities around the colony. As a result of further scouting in 1913 and 1914 it was found that they were rapidly spreading and increasing.

Medford.—No beetles were liberated here, but in 1910 indications of their presence were noted in the northern part of the city. Later reports show them to be common in all the woodland areas.

Medway.—In 1913, 100 beetles were liberated in Black Swamp. They were recovered in a few woodland areas in 1914.

Melrose.—During 1909, 200 beetle larvæ were liberated in woodland near the Saugus-Wakefield line. Beetles were found in small numbers throughout the entire area in 1910. This species at the present time is common and doing efficient work in all the woodland areas.

Merrimac.—Two hundred beetle larvæ were liberated north of Main Street, in Nichols Woods. Molt skins were secured in a few localities in 1912. In 1913 and 1914 they had become quite common in some sections.

Methuen.—During 1910, 200 beetle larvæ were liberated in the eastern part of the town near the Haverhill line. Their presence was noted in 20 or more localities in 1912, and a constant increase and spread has been reported since that time.

Middleboro.—In 1913, 85 beetles were liberated in woodland infested by the gipsy moth off Wareham Street. This species was recovered in all parts of the town in 1914.

Middleton.—One hundred beetles were liberated in woodland off East Street in 1910, and in 1911 they were recovered in a number of localities. Further examinations in 1912 showed that the beetles were still increasing and had become well established in 1913 and 1914.

Milford.—No liberations were made in this town, but it was reported that beetles were seen in the northern part of the town, near the Hopkinton line, in 1914.

Milbury.—No beetles were liberated here, but scouting in 1914 showed them to be present in small numbers in some parts of the town.

Millis.—In 1913, 100 beetles were liberated in the northern part of the town, and in 1914, 95 adults were liberated in the eastern part. As a result of examinations in 1914, it was found that this species had spread rapidly and could be found in all sections of the town.

Milton-Quincy.—During 1909, 200 beetle larvæ were liberated near Shawmut Spring, in Cunningham Park. In 1912 beetles were recovered in 14 different localities of the former town. This species became very abundant in 1913 and 1914 in badly infested sections.

Natick-Weston.—Two hundred larvæ were liberated near the Natick-Weston line in 1910. Larval molt skins were found in a few localities in Natick in 1911. Evidences of the beetles were noticed in 1912 and in 1913, and by 1914 this species had become very abundant in some localities.

Needham.—In 1911, 100 beetles were liberated in woodland off Central Avenue. During 1912 examinations showed them to be present in five or more localities. Data secured in 1913 and 1914 indicated that the species was spreading and increasing rapidly.

Newbury.—During 1910, 88 beetles were liberated in badly infested woodland near Byfield Station. In 1912 they were recovered in several sections throughout the town. Later reports show them to be quite common in areas infested by gipsy moths.

Newburyport.—During 1910, 200 beetle larvæ were liberated in woodland near West Newbury line. Larval molt skins were found in several locations in 1912. In 1913 and 1914 the beetles were very abundant in all the woodland areas.

Newton.—In 1908, 100 beetle larvæ were liberated, and in 1909 400 more were colonized in two other localities. During 1910 they were recovered in and around the colonies. As a result of examinations in 1911 they were found in most of the wooded sections of the city, and later reports indicate that they are quite common in all the districts infested by gipsy moths.

Norfolk.—Ninety beetles were liberated in the western part of this town near Populatic Pond in 1914. Later they were recovered in localities around the colony.

North Andover.—In 1910, 100 beetles were liberated in badly infested woodland off Osgood Street. Scouting in 1912 showed them to be present in a number of localities. In 1913 and 1914 they were reported numerous, and in some cases the larvæ had consumed nearly all the gipsy-moth pupæ on the trees 8 feet from the ground.

Northboro.—During 1913, 190 beetle larvæ were liberated near the Metropolitan Aqueduct. As a result of examinations in 1914 they were found to be present in a number of localities.

North Reading.—In 1910, 200 beetle larvæ were liberated in woodland one-half mile from the State road. They were recovered in a few separated woodlands in 1911. During 1912 this species was quite common in a number of localities, and later reports indicate that they are abundant in all the woodland areas.

Norton.—During 1914, 95 beetles were liberated in the eastern part, and 90 more in the northern part of the town.

Norwell.—*C. sycophanta* beetles were found in the northwestern part of the town in 1912. In 1913, 308 beetle larvæ were liberated in woodland off Main Street, in a rather heavy gipsy-moth infestation. Examinations made later in the year showed them to be present in many localities and in 1914 rapidly increasing.

Norwood.—No beetles were liberated in this town, but they were found in one locality in 1912. Scouting in 1913 showed them to be present in all sections of the town, and in 1914 they were found to be abundant in several wooded areas.

Peabody.—Fifty beetles were liberated in a badly infested woodland in 1907. In 1909, 100 beetles were liberated in woodland near Middleton Paper Mills, 100 beetle larvæ off Birch Street, and 200 larvæ in woodland off West Street, near West Peabody Station. Several woodlands were examined in 1911 and molt skins were found in many locations. During 1912 the adults of this species were seen in large numbers by the inhabitants of West Peabody. Evidence of the beetles' good work was seen in all localities in 1913 and 1914.

Pembroke.—No liberations were made here, but examinations in 1913 showed them to be present in all localities, being well established in the southern part of the town. In 1914 they were more common in most sections where gipsy moths were present in sufficient numbers.

Pepperell.—No beetles were liberated here, but several woodlands were examined in 1913, and larval molt skins were found in a few localities. In 1914 this species was common and doing efficient work in all the woodland areas.

Phillipston.—No liberations were made here, but in 1914 three beetles were seen in the northern section of the town about $1\frac{1}{2}$ miles south of South Royalston Station. These undoubtedly dispersed from the colony liberated at East Templeton in 1913.

Plymouth.—In 1911, 21 beetles and 135 beetle larvæ were liberated on the estate of Mr. B. M. Watson. They were recovered in and around the colony in 1913. Examinations in 1914 showed them to be present in moderate numbers in the northern and central parts of the town.

Plympton.—No liberations were made here, but in 1914 larval molt skins were found in all sections of the town where gipsy moths were present in sufficient numbers.

Princeton.—In 1913, 195 beetle larvæ were liberated in woodland off East Princeton road. During 1914, 180 beetles were liberated at John Chandler's farm, on Princeton-West Sterling road. Later reports show this species to be increasing and spreading satisfactorily.

Provincetown.—In 1914, 100 beetles were liberated in badly infested woodland in Province Lands.

Quincy.—During 1909, 200 beetle larvæ were liberated in woodland off South Street. In 1910 the adults and larvæ were found in abundance in and around the colony; 134 beetle larvæ were added to this colony in 1911. This species was recovered in 1912 in several localities far remote from the site of the original colony. In 1913 and 1914 they had continued to increase and spread rapidly.

Randolph.—No liberations were made here, but larval molt skins were found in a number of sections throughout the town in 1913. A slight increase and spread was noted in 1914.

Raynham.—In 1913, 100 beetles were liberated in woodland at the corner of Forest and Locust Streets. During 1914, 100 beetles were colonized in the central part of the town. This species is spreading rapidly and doing good work in limited localities.

Reading.—No colonies have been liberated here, but larval molt skins were found in the southeastern and central parts in 1910. Scouting in 1911 showed them to be present over the whole area, and in some cases quite numerous. In 1912 larvæ were found commonly throughout. Later reports indicate that they are very numerous and doing efficient work in the infested areas.

Revere.—During 1908, 300 beetle larvæ were colonized in infested woodland on Oak Island. Some visits were made in and around the colony in 1911 and they were seen in large numbers. Later reports indicate that this species is well established.

Rockland.—In 1913, as a result of scouting several woodlands in various parts of the town, it was found that larval molt skins were present in several widely separated districts. During 1914 the beetles had increased rapidly and were doing very efficient work in gipsy-moth infested areas.

Rockport.—In 1910, 200 beetle larvæ were liberated in woodland in the rear of Manning Park. Larval molt skins were found present in several widely separated districts in 1912. During 1913 and 1914 they had become quite common in a number of localities.

Rowley.—Two hundred beetle larvæ were liberated in infested woodland off the Newburyport Turnpike in 1910. During 1912 several examinations were made and it was found that the beetles were present in several localities. Later reports indicate that the species is present in all sections where gipsy moths are found in sufficient numbers.

Rutland.—No liberations were made here, but a few beetles were reported from the eastern part of the town in 1914.

Salem.—No colonies have been liberated in this city, but in 1910 an examination showed them to be present over a large area in the southern part of the city. Scouting in 1911 indicated that they had increased and spread over a much larger area. This species at the present time is common in all the infested districts.

Salisbury.—In 1910, 200 beetle larvæ were liberated in infested woodland, and during 1912 they were recovered in several of the wooded areas. In 1913 and 1914 the species was common in all sections of the town and quite a number were seen around the cottages at Salisbury Beach.

Sandwich.—No beetles were liberated in this town, but as a result of scouting in 1914 it was found that they were present in small numbers in the southeastern and southern parts.

Saugus.—During 1906, 49 beetles were liberated in woodland in the northern section. In 1907, 33 beetles were liberated in infested woodland north of the former gipsy-moth laboratory at North Saugus. During 1911, 34 beetles were seen by Mr. C. W. Collins in a small area in the above district. Two hundred and fifty beetles to be used for transplanting were collected in a small woodland in the northern part of the town in 1913, showing that the beetles were quite numerous. This species has spread rapidly and was well established in all parts of the town in 1914.

Scituate.—In 1911, 835 beetle larvæ were liberated in a woodlot at the corner of Elm and Main Streets. Examinations in 1912 showed them to have multiplied and spread quite a distance from the center of the colony. Later reports indicate that they had dispersed to all parts of the town and were well established.

Sharon.—One hundred beetles were liberated in woodland near Sharon Sanitarium in 1913. During 1914 several localities were scouted and larval molt skins were found in a number of infested districts.

Sherborn.—During 1910, 200 beetle larvæ were liberated in infested woodland off Main Street. Examinations were made in scattered woodlands throughout the town in 1913 and larval molt skins were recovered in several localities. In 1914 they continued to increase and spread and had become well established.

Shirley.—No liberations were made here, but examinations made in 1913 and later reports in 1914 showed the beetles to be present in several separated districts.

Shrewsbury.—In 1913, 250 beetle larvæ were liberated in an apple orchard off Oak Street and 90 adults in the northern part of the town in 1914. As a result of scouting in 1914, it was found that this species was present in all locations where gipsy moths were present in sufficient numbers.

Southboro.—No colonies were liberated here, but in 1913 beetles were found in one locality in the eastern section. During 1914 they had increased and spread to other localities.

Sterling.—During 1913, 200 beetle larvæ were liberated in woodland near the post office. In 1914 larval molt skins were found in all parts of the town, but in small numbers, showing that the beetles had spread and will in time become abundant.

Stoneham.—In 1908, 75 beetles were liberated in woodland off Franklin Street. During 1909 a few of these were recovered. Larval molt skins were found in the eastern and southern parts of the town in 1910. In 1911 and 1912 this species had increased and spread throughout, being very abundant in some localities. Since that time the beetles have become abundant in all gipsy-moth infested areas.

Stoughton.—During 1911, 100 beetles were liberated in infested woodland off Turnpike Street. In 1914 larval molt skins were found in one locality. Infestations in most sections of the town were very light, hence the slow increase of beetles.

Stow.—Eighty-six beetles were liberated in this town in 1910. In 1912 larval molt skins were found in 11 or more separated localities. This species had become well established in 1913 and 1914 and could be found very abundant in some sections of the town.

Sudbury.—In 1910, 200 beetle larvæ were liberated in woodland in East Sudbury. Larval molt skins were recovered in a few localities in 1911, and in 1912 had increased and spread to most sections of the town. Reports received in 1913 and 1914 show this species to be present in all sections and in some cases very abundant.

Sucampscott.—During 1908, 175 beetle larvæ were liberated in woodland off Danvers Street and 200 larvæ were colonized north of the Ocean House. In 1910 beetles were recovered in and at some distance from the colonies. This species had increased and spread to a number of localities in 1911 and 1912. Later reports indicate a similar increase and spread.

Taunton.—In 1913, 100 beetles were liberated off Bay Street, and in 1914, 95 adults were colonized in woodland in the southeastern part of the city. Recoveries were made near the colonies in 1914.

Templeton.—During 1913, 200 beetle larvæ were liberated off Petersham Road. Beetles were recovered in and near the colony in 1914.

Tewksbury.—In 1908, 100 beetle larvæ were liberated in woodland infested by gipsy moths. During 1910, 100 beetles were liberated off Shawsheen Avenue and 200 larvæ near Prospect Hill. In 1912 larval molt skins were recovered in 12 or more widely separated localities. Since that time the beetles have spread and become quite abundant in a number of the infested woodlands.

Topshfield.—In 1910, 180 beetle larvæ were liberated off High Street. During 1911 some scouting was done and larval molt skins were found in several woodlands. During 1912 molt skins were found in eight or more different localities. Further reports in 1913 and 1914 showed that the beetles had increased and become well established throughout.

Townsend.—No liberations were made in this town, but a few molted skins were found in two well-separated localities in 1913. Reports from here in 1914 show that the beetles were very plentiful, and could be found in most of the infested areas.

Tyrngsboro.—No beetles were liberated here, but in 1912 several woodlands were examined, and larval molt skins found in a number of well-separated localities. Further data secured in 1913 and 1914 indicated that the beetles

had increased extensively, and results of their work were becoming very evident.

Wakefield.—No beetles were colonized here, but in 1909 they were found in the eastern part of the town, and in 1910 could be found in various localities. During 1911 and 1912 they had increased and spread throughout, and are now assisting greatly in lessening the damage done by the gipsy moth.

Walpole.—In 1913, 100 beetles were liberated in a wood lot off North Street. As a result of scouting in 1914, it was found that this species was present in several localities throughout the town.

Waltham.—During 1908, 100 beetle larvæ were liberated off Lake Street. In 1910 they were recovered in and at some distance from the original colony. During 1911 a general scout was made, and molt skins were found in most of the woodlands visited. Since that time the beetles have become well established, and are very abundant in some localities.

Wareham.—No liberations were made here, but as a result of scouting during 1914 the species was found to be present in a few localities in the northwestern part of the town.

Watertown.—No beetles were liberated, but evidences of their presence were noted in several localities in 1911. Since that time they have increased and spread throughout all the woodland areas.

Wayland.—During 1909, 200 beetle larvæ were liberated in infested woodland off Poor Farm Road. In 1910 they were recovered in and around the original colony. During 1911 and 1912 the beetles had spread and become well established in the infested areas. Further reports indicate that they are still increasing and have become quite abundant in several localities.

Wellesley.—In 1908, 223 beetles were liberated in infested woodland near Wellesley Farms Station. In 1909 they were recovered in and at some distance from the original colony, while in 1910 they were scattered over a larger area. During 1911 larval molt skins were recovered in practically all parts of the town. In 1912 the beetles had increased to such an extent that over 2,000 larvæ were collected under burlaps for further colonization without depleting the stock. In 1913, 3,500 beetle larvæ were collected in a limited area of the town, and during 1914 beetles were collected in large numbers for recolonization.

Wenham.—In 1908, 12 beetles and 75 beetle larvæ were liberated off Cherry Street. During 1909, 73 beetles and 100 beetle larvæ were colonized off Grapevine Road. In 1910 beetles were found in and at quite a distance from the original colonies. During 1911 and 1912 the species had increased and spread over large areas. Since that time they have become well established, and in some localities very abundant.

Westboro.—No liberations were made here, but in 1914 beetles were found in a number of localities throughout the town.

West Boylston.—In 1914, 90 beetles were liberated in infested woodland off Prescott Street. During the late summer larvæ were seen in large numbers in and around the colony.

West Bridgewater.—No beetles were liberated here, but in 1914 some scouting was done, and larval molt skins were found in the southwestern part of the town.

Westford.—During 1910, 100 beetle larvæ were liberated in the northern part of the town. Examinations in 1912 showed that the beetles had spread over a rather large area in the eastern section. In 1913 and 1914 further reports indicated that they had increased and were becoming quite numerous.

Westminster.—In 1913, 100 beetles and 200 beetle larvæ were liberated near Bean Porridge Hill, and in 1914, 87 adults were colonized off Westminster Hill

Road. Scouting was done in 1914, and this species was recovered in and at some distance from the original colonies.

Weston.—During 1909, 200 beetle larvæ were liberated in woodland near railroad station. Several larval molt skins were found in the area surrounding the colony in 1910. In 1911 the beetles had spread to all sections, and in some cases quite numerous. Later reports indicate that they have become well established in all parts of the town.

West Newbury.—Two hundred beetle larvæ were liberated on Pipestave Hill in 1910. Scouting in 1912 resulted in finding molt skins in several well separated localities. Later data secured show that they are very common in all the infested woodlands.

Westwood.—In 1910, 200 beetle larvæ were liberated in badly infested woodland, and in 1911, 100 beetles were colonized in woodland off Canton Street. Several woodlands were scouted in 1912, and molt skins were found over the entire area. Since that time this species has become common throughout.

Weymouth.—During 1909, 200 beetle larvæ were colonized in woodland off Commercial Street. In 1910 molt skins were found abundant in and around the colony. During 1911 and 1912 the beetles had become well distributed throughout, and in 1913 and 1914 they had increased extensively.

Wilmington.—Two hundred beetle larvæ were liberated near the central part of the town in 1910. In 1911 it was found that the beetles had spread throughout. During 1913 and 1914 they had become so numerous that it was possible to collect many adults and larvæ for further colonization work.

Winchester.—In 1906, 41 beetles were liberated off High Street. During 1910 larval molt skins were found quite a distance from the original colony. Examinations in 1911 showed that the beetles had dispersed over a greater part of the town and since that time have continued to increase.

Woburn.—During 1907, 97 beetles were liberated in woodland near North Woburn. In 1909 beetles were found in the colony, and larval molt skins were found a mile distant. Data secured in 1910 and 1911 showed that the beetles had increased considerably and had dispersed to all sections of the city. Since that time this species has continued to increase, and is common in all the woodland areas infested by gipsy moths.

Worcester.—In 1913, 150 beetle larvæ were liberated in an apple orchard at the corner of Pleasant and Moreland Streets. Larval molt skins were found quite abundantly in the western part of the city in 1914, and a colony of 90 beetles was liberated the same year near Lake Quinsigamond.

Wrentham.—In 1914, 90 beetles were liberated in the northern part of the town, off Bennett Street.

NEW HAMPSHIRE.

Allenstown.—No colonies were liberated in this town, but in 1913 beetles were found in the southern part. In 1914 they had spread to all sections.

Alton.—In 1914, 90 beetles were liberated in this town near Spring Haven Station, 90 north of Alton Station, and 90 near Merry Meeting Pond, the last being colonized by Prof. W. C. O'Kane.

Amherst.—Although no colonies were liberated in this town, evidence secured in 1913 showed that the beetles were present in 10 or more widely separated localities, and in 1914 had become quite common.

Andover.—In 1914 beetles were found in the eastern part of the town, although no liberations were made.

Atkinson.—Larval molt skins were found in several different localities in this town during 1912. Later reports show them to have become well established.

Auburn.—In 1913 beetles were found present in several localities and during 1914 they had become quite common.

Barnstead.—During 1914, 42 beetle larvæ were liberated in the central part of this town by Prof. W. C. O'Kane. Later they were recovered in the eastern part, where they had spread from other towns.

Barrington.—Although no colonies were liberated here, larval molt skins were found in several sections during 1914.

Bedford.—Scouting during 1913 showed that the beetles were present in several areas and in 1914 they had become quite numerous.

Boscawen.—No liberations were made here, but beetles were found in two widely separated localities in 1914.

Bow.—In 1913, 85 beetles were liberated in woodland near Bow Mills. During 1914 they were found in a number of well-separated sections.

Brookfield.—During 1914, 100 beetles were liberated 2 miles west of Sanbornville Station, 77 on road to Coplecrow Mountain (4 miles from Sanbornville Station), and 56 beetle larvæ one-half mile north of Brookfield Center. The two latter colonies were liberated by Prof. W. C. O'Kane.

Brookline.—No colonies were liberated in this town, but larval molt skins were found in the northern part in 1913, and during 1914 they had increased and spread to a number of localities.

Candia.—During 1913 larval molt skins were found in several scattered woodlands, showing that the beetles had dispersed here from other near-by sections. Further data secured in 1914 show that the beetles were common throughout.

Canterbury.—One hundred beetles were liberated in this town in 1913. They were recovered in six widely separated localities in 1914.

Chester.—Beetles were found to be present in a number of localities in this town during 1913 and 1914.

Chichester.—In 1914, 100 beetles were liberated in the southern part of the town by Prof. W. C. O'Kane. Larval molt skins were also found in this section in 1914.

Concord.—In 1913, 85 beetles were liberated in woodland near West Concord post office. During 1914 larval molt skins were found in all the infested woodlands.

Danville.—Examinations of some woodlands in 1913 showed that the beetles had dispersed here, and in 1914 were well distributed over the entire area.

Deerfield.—No liberations were made here, but in 1914 the beetles were common throughout, and in some localities very abundant.

Deering.—During 1914 beetles were found quite abundant in two well-separated localities.

Derry.—During 1912 and 1913 larval molt skins were found in several widely separated localities. Since that time they have become well established throughout.

Dover.—No colonies were liberated here, but in 1913 and 1914 larval molt skins were found in well-separated localities.

Dunbarton.—As a result of scouting in 1914, beetles were found in six well-separated localities.

Durham.—No beetles were liberated here, but in 1913 and 1914 they had become well established in all parts of the town.

Eppingham.—During 1914, 100 beetles and 68 beetle larvæ were liberated in this town by Prof. W. C. O'Kane.

Epping.—During 1913 examinations of woodland showed that the beetles had entered this town, and were present over a limited area. They were reported quite common throughout in 1914.

Epsom.—In 1914, 100 beetles were liberated three-fourths of a mile from Short Falls Station by Prof. W. C. O'Kane.

Exeter.—No liberations were made here, but in 1912 beetles were found in the eastern and southern sections. In 1913 and 1914 they had spread to all parts of the town and were increasing extensively.

Farmington.—Examinations in 1914 showed the beetles to be present in eight widely separated localities.

Fitzwilliam.—In 1914, 300 beetles were colonized in three widely separated localities in this town.

Francistown.—In 1914, as a result of scouting, larval molt skins were found in the eastern, southern, and central parts of this town.

Fremont.—No beetles were liberated here, but in 1912 they were found in three different localities in the southern part of the town. In 1913 and 1914 they had become well established in all the infested woodlands.

Goffstown.—During 1913, 100 beetles were liberated in woodland near Sawyers Crossing. Larval molt skins were found in the northern, western, and south-central parts of the town in 1914, and were abundant in some sections.

Gilmanton.—In 1914, 90 beetles were liberated in the northwestern part of the town. Later the same year 61 beetle larvæ were colonized by Prof. W. C. O'Kane.

Greenville.—In 1914 beetles were reported from all sections of the town.

Hampstead.—During 1912 larval molt skins were found in a few localities. Further reports indicate that they are well established throughout the town.

Hampton.—Examinations of woodlands during 1912 showed that the beetles had dispersed into the town. In 1913 they were found quite commonly in several localities, and during 1914 they were well established in all the woodland areas.

Hampton Falls.—Beetles were found in small numbers in this town during 1912, and in 1913 and 1914 they were reported very abundant in some localities.

Henniker.—In 1914, 54 beetles were liberated in the northwestern part of this town. Later in the year they were recovered in the northeastern, eastern, and southern sections.

Hollis.—In 1912 beetles were found in four or more separated localities. Since that time they have increased and spread to all the infested woodlands.

Hooksett.—Eighty-five beetles were liberated here in 1913. Later in the year larval molt skins were found in a few scattered localities, indicating that the beetles had also spread here from neighboring towns. During 1914 they had become well established throughout.

Hopkinton.—During 1913, 85 beetles were liberated here. In 1914 they were found in the southeastern, eastern, and northwestern parts of the town.

Hudson.—A number of localities were scouted in this town in 1912 and 1913, and larval molt skins were found in many sections. In 1914 they had continued to increase and spread to all infested areas.

Kensington.—Evidences of the beetles' presence were found in this town during 1912. Since that time they have increased and spread to all the infested woodlands.

Kingston.—Beetles were found present here in several localities in 1912. During 1913 and 1914 they had increased and dispersed to all the gipsy-moth infested areas.

Lee.—In 1913 beetles were found in a few separated localities, and during 1914 they had continued to increase and spread to all sections of the town.

Litchfield.—Larval molt skins were found in three or more separated localities in this town during 1913, and in 1914 they had become quite common.

Londonderry.—No liberations were made here, but larval molt skins were found in 12 different localities in 1913. They were reported doing efficient work in the infested woodlands in 1914.

Louden.—In 1914 larval molt skins were found in small numbers in the northeastern part of the town.

Lyndeboro.—Beetles were found in the southeastern part of the town in 1913, and during 1914 they had increased and spread to a number of well-separated localities.

Madbury.—During 1913 beetles had made their appearance in a few localities, and in 1914 they were well distributed throughout the town.

Manchester.—In 1913, 100 beetles were liberated in woodland off Mammoth Road. Later examinations showed that they were present in several localities; this species evidently had spread from nearby towns, and in 1914 was reported common throughout.

Mason.—A few beetles were found in the eastern part of this town in 1913, and in 1914 they were reported from various localities.

Merrimac.—Larval molt skins were found in several widely separated localities in 1913. During 1914 they had become well established throughout.

Middleton.—Seventy-one beetle larvæ were liberated in woodland off Ridge Road by Prof. W. C. O'Kane in 1914.

Milford.—Evidence of the beetles' presence was found in a number of localities in this town during 1914.

Milton.—In 1913, 200 beetle larvæ were liberated off State road near railroad station. During 1914, as a result of scouting, they were found in all parts of the town.

Mont Vernon.—Larval molt skins were found in four well-separated localities in 1913. Since that time this species has continued to increase and is doing efficient work in the infested areas.

Nashua.—In 1912 and 1913 larval molt skins were found in a number of well-separated localities. Reports in 1914 show that they are quite common throughout.

New Boston.—During 1913, 85 beetles were liberated in woodland off Francistown Road, and 85 more near Old Muzzy Hill. In 1914 larval molt skins were found in all sections of the town, being quite abundant in some localities.

New Durham.—In 1914, 90 beetles were liberated in woodland southwest of Davis Station and 104 were colonized by Prof. W. C. O'Kane off road from New Durham to Farmington.

Newfields.—Evidence of the beetles presence in this town was found in several woodlands during 1913 and 1914.

Newington.—A few larval molt skins were found near the Portsmouth line in 1912, and during 1913 the beetles had spread over the greater part of the town. In 1914 they were well established in all the woodlands infested by gipsy moths.

New Ipswich.—In 1913, 100 beetles were liberated in a woodland off King Road. Examinations here in 1914 showed that the beetles were present in a few separated localities.

Newmarket.—Larval molt skins were found in a few localities near the center of the town in 1913. Since that time they have increased and spread to all sections.

Newton.—In 1913 and 1914 beetles were found in a number of separated localities. Later reports indicate that they are still present and increasing.

North Hampton.—Beetles were found present here in a few localities in 1912. Data secured since that time show that they have become well established, being abundant in some localities.

Northwood.—Beetles were found here in a few localities in 1914.

Nottingham.—Scouting in this town during 1913 showed the beetles to be present in the eastern and central sections, and in 1914 they were well distributed throughout.

Ossipee.—In 1914, 32 beetle larvæ were colonized in woodland near Leightons Corner by Prof W. C. O'Kane.

Pelham.—Larval molt skins were found in a number of localities in 1912. During 1913 and 1914 they had increased and spread to all sections of the town.

Pembroke.—During 1913 larval molt skins were found in a few localities in the southern part of the town and in 1914 they were present in most of the infested woodlands.

Pittsfield.—In 1914 larval molt skins were found in the southwestern corner of this town.

Plaistow.—Examinations made here during 1912 and 1913 showed that the beetles were well established, and in 1914 they were found very abundant in some localities.

Portsmouth.—Examinations during 1912 showed that the beetles were present in a few localities, and in 1913 and 1914 they were common throughout the woodland areas.

Raymond.—A careful scout made here in 1913 showed the beetles to be present in several localities. Since that time they have continued to increase and are doing efficient work in the gipsy-moth infested areas.

Richmond.—Beetles were found here in small numbers in 1914.

Rindge.—During 1913, 40 beetles and 102 beetle larvæ were liberated in the southern part of the town, and in 1914, 100 beetles were liberated in a woodland $1\frac{1}{2}$ miles east of West Rindge station.

Rochester.—In 1913 larval molt skins were found in the southern part of the town and during 1914 they were recovered in nine well-separated localities.

Rollingsford.—As a result of examinations in 1914 beetles were found to be common in a number of well-separated woodlands.

Rye.—No liberations were made here, but larval molt skins were found in moderate numbers during 1912 and 1913. In 1914 they had become well established throughout.

Salem.—Beetles were found present in a number of localities in this town during 1912. Since that time they have continued to increase and spread to all the infested areas.

Sandown.—Larval molt skins were found here in a few localities in 1912. In 1913 and 1914 the beetles had dispersed to all the infested areas.

Sandwich-Tamworth.—In 1909, 100 beetle larvæ were liberated near Sandwich-Tamworth line, in woodland which was being defoliated by *Heterocampa guttivitta* Walk. and *Anisota rubicunda* Fab. Gipsy moths had not been found in this region, but it was desired to see whether the beetles would feed on these species and survive the winter. In 1910 and 1913 scouting was done, but no beetles were recovered.

Seabrook.—During 1912 examinations were made in several parts of the town and as a result larval molt skins were found in a few localities. Further data secured in 1913 and 1914 showed that the beetles had increased extensively.

Somersworth.—No liberations were made, but in 1914 larval molt skins were found in a number of well-separated localities.

Southampton.—Scouting in 1913 showed the beetles to be present in a few localities in the western part of the town. Since that time they have continued to increase and spread to the infested woodlands.

Strafford.—During 1913 and 1914 examinations were made in several woodlands, and larval molt skins were found in a few well-separated localities.

Stratham.—In 1912 and 1913 larval molt skins were recovered in a few separated wooded areas of the town, indicating that the beetles had spread from other near-by sections. During 1914 the beetle had become quite common throughout.

Temple.—During 1913, 100 beetles were liberated in infested woodland on Haywood Hill. Scouting in 1914 showed them to be present in a few well-separated localities.

Wakefield.—In 1914, 100 beetles were liberated in woodland on the southwestern shore of Great East Pond, and 100 more were colonized in this town by Prof. W. C. O'Kane.

Weare.—No liberations were made here, but larval molt skins were found in four well-separated localities in 1914.

Webster.—During 1913, 85 beetles were liberated in woodland near Holmes Hill. In 1914 they were recovered in and around the colony, also in the southeastern and southwestern parts of the town.

Wilton.—During 1913, 100 beetles were liberated in infested woodland on Abbott Hill. Examinations in 1914 showed that they were well distributed and quite abundant in some localities.

Windham.—Examinations made here in 1912 showed that the beetles were present in a few localities in the eastern and southern parts of the town. In 1913 and 1914 they had increased considerably, and were doing very efficient work in a number of infested woodlands.

MAINE.

In 1908, 100 *Calosoma* larvæ were shipped by express to Capt. E. E. Philbrook, Portland, Me. They were packed separately in glass tubes with earth and liberated by him in Kittery and Wells. Subsequent examinations have shown that the places selected for making liberations were not particularly suitable for the purpose, as the infestations were so scattering that a sufficient quantity of food was not available for the development of the larvæ. In 1913 scouting and liberation of colonies was done by employees of the Maine Department of Agriculture working in cooperation with the Bureau of Entomology.

Colonies were liberated by the above organization in 1914, but we have no records as to the localities.

Alfred.—Examinations in this town in 1914 showed the beetles to be present in three localities in the central part of the town.

Berwick.—Larval molt skins were found in three localities in the central and southeastern part of the town in 1914.

Biddeford.—Beetles were recovered in three well-separated localities in 1914.

Dayton.—Larval molt skins were found in the north-central part of the town in 1914.

Elliot.—A few beetle larvæ were found here in 1913, and in 1914 they had become common in all parts of the town.

Kennebunk.—In 1914 beetles were reported from two localities in this town.

Kennebunkport.—The gipsy-moth infestation was rather light in this town in 1914, but beetles were found in one locality.

Kittery.—In 1908, 140 beetle larvæ were liberated in three different localities in this town. Scouting was done in 1913 and molt skins were recovered. During 1914 they had spread to all sections and were increasing extensively.

Lyman.—Larval molt skins were found in two localities during 1914.

North Berwick.—In 1914 as a result of scouting larval molt skins were found in two localities in the eastern part and two in the northern part of the town.

Portland.—During 1913, 27 beetles were liberated in woodland near St. Joseph's Academy. They were recovered in the city in 1914.

Saco.—Larval molt skins were found in one locality in the central part of the town in 1914.

Sanford.—In 1914 beetles were found to be present in four widely separated localities.

Shapleigh.—Examinations here in 1914 showed that the beetles were present in three localities.

South Berwick.—Beetle larvæ were found quite abundant in all the areas infested by gipsy moths in 1914.

Wells.—In 1908, 30 beetle larvæ were liberated in this town. In 1914 larval molt skins were recovered in five widely separated localities.

York.—During 1908, 30 beetle larvæ were liberated in the town and 127 adults were colonized in another locality in 1913. In 1914 beetles were recovered in several localities throughout.

RHODE ISLAND.

Cumberland.—In 1913, 200 beetle larvæ were liberated in a gipsy-moth infested woodland near Diamond Hill Reservoir. They were recovered in and around the colony in 1914.

Newport.—During 1914, 110 beetles were liberated in woodland on Miantonomi Hill.

Providence.—In 1913, 170 beetles were liberated in this city; 85 in infested willows off Kay Street, and 85 in Davis Park. They were recovered in and at some distance from the colonies during 1914.

CONNECTICUT.

Stonington.—In 1914, 220 beetles were liberated in this town in two localities where *Malacosoma americana* were very abundant, and gipsy moths had been present.

Thompson.—No liberations were made here, but beetles were found in small numbers in 1914 as a result of spread from Massachusetts towns.

ECONOMIC IMPORTANCE OF CALOSOMA SYCOPHANTA.

This insect has now become firmly established in New England. It is reproducing satisfactorily and has already demonstrated that it is a very important factor in the control of the gipsy moth by natural enemies. The beetle is now abundant enough so that it is frequently seen by many residents of the territory where it was first liberated, and a large number of people are familiar with its habits and methods of destroying the gipsy moth. There are a number of very strong

points which increase the usefulness of this insect. The life history of the beetles and the larvæ corresponds very closely to that of the larval and pupal stages of the gipsy moth, so that they are especially adapted to attack this pest. The climbing habits of the *Calosoma* larvæ enable these creatures to obtain food upon the trees and in this way an opportunity is furnished for the species to increase in large numbers. The fact that the adults commonly live 2 or 3 years, and sometimes 4 years or more, makes it possible for the species to survive under unfavorable conditions. The chances for the species to exist are further increased by the fact that reproduction by the same individuals may occur on alternate years. The species is capable of existing for long periods without food, and passes through hibernation very successfully under New England climatic conditions. All these factors make it an excellent addition to our fauna, and from the results which have been secured from experimental records and in the field it appears that the species at present ranks first among the introduced natural enemies of the gipsy moth. During the summer of 1914 a large amount of field data was secured to determine the relative importance of the different natural enemies of this insect. The results of 1914 indicate that the *Calosoma* beetle was the most important single factor. The insect continues to spread each year, and in all probability will soon be present throughout the entire territory where the gipsy moth is known to exist. There is no good reason to suppose that it may not spread in small numbers to places outside this territory if sufficient and proper food can be found.

Beetles sent to New Brunswick, Canada, survived the winter satisfactorily, and the same is true of specimens forwarded to New Mexico, which indicates that the insect is able to survive under quite different climatic conditions.



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LIFE HISTORY OF THE CODLING MOTH IN MAINE.

By E. H. SIEGLER and F. L. SIMANTON, *Entomological Assistants, Deciduous Fruit Insect Investigations.*

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INTRODUCTION.

A temporary field station of the United States Bureau of Entomology was established at Winthrop, Me., in the spring of 1913, under the direction of Mr. A. L. Quaintance, in charge of deciduous fruit insect investigations. Mr. E. H. Siegler, of the Bureau of Entomology, was assigned to this station for the purpose of studying the life history of the codling moth (*Carpocapsa pomonella* L.) under Maine conditions. Owing to the transfer of Mr. Siegler in 1914 to another station, Mr. F. L. Simanton was detailed to complete the investigations. The records of the observations, herewith reported, cover the seasons of 1913 and 1914, during part of which time the writers were assisted by Mr. E. R. Van Leeuwen.

In order to ascertain the variations in the life history of the codling moth under diverse climatic conditions, investigations have now been completed in widely separated districts, such as Maine and New Mexico, as well as in representative intermediate localities. The methods of study have been essentially the same wherever the work has been undertaken. In this bulletin a detailed account of the life history of the codling moth is reported as well as brief mention of the means of control.

DEFINITION OF TERMS.

The following terms and definitions have been adopted for this report.

The term brood is used for any stage of any generation of the insect. Thus, first-brood larva refers to a larva of the first generation; spring-brood larva has reference to a larva of either the first or second generation.

Generation is used to include all of the stages of the insect, from the egg to the adult stage.

The life cycle of a generation herein recorded includes the time from the deposition of the egg until the emergence of the moth.

The complete life cycle includes the time from the deposition of the egg of one generation to the deposition of the egg of the next generation.

The term wintering larvæ has reference to the larvæ which winter in the larval stage. It includes all larvæ which do not transform during the same season as hatched.

The wintering larvæ transform in the spring to pupæ, known as spring-brood pupæ (spring pupæ). These in turn transform to spring-brood moths (spring moths). The spring pupæ and spring moths, although the first to appear in the calendar year, are not designated as first-brood pupæ and first-brood moths. The first-brood pupæ and the first-brood moths appear later in the season and are the pupæ and moths of the first generation. These may be conveniently designated summer pupæ and summer moths.

The terms used for Maine conditions are defined as follows:

Wintering larvæ: Include overwintering larvæ of the first and second broods.

Spring-brood pupæ: Include the pupæ from the overwintering larvæ.

Spring-brood moths: Include the moths from the spring pupæ.

The first generation includes:

1. The first brood of eggs.
2. The first brood of larvæ, which includes
 - (a) transforming larvæ;
 - (b) overwintering larvæ.
3. The first brood of pupæ, or summer pupæ.
4. The first brood of moths, or summer moths.

The second generation (not complete in Maine) includes:

1. The second brood of eggs.
2. The second brood of larvæ. None of these larvæ transform until the following spring.

SEASONAL-HISTORY STUDIES OF 1913.

The codling-moth life-history investigations were conducted under outdoor conditions, so that the results obtained would represent, as nearly as possible, the normal life of this insect in the field. Accordingly the rearing work was carried on in an open shelter erected for this purpose.

As a basis of comparison the laboratory methods were checked with field observations chiefly by means of banded trees. The apple trees were prepared for banding by removing the loose bark from the trunk and main limbs. A burlap band of three thicknesses and about 5 inches in width was then placed tightly around the trunk about 3 feet above the base and held in place by an 8-penny wire nail. The larvæ were collected from these banded trees every three days. These larvæ hatched and fed under natural conditions, and hence their time of leaving the fruit and their subsequent life history should correspond with those of the larvæ reared by the laboratory methods.

The general method for carrying out the life-history studies is illustrated in Plate II, figure 1. The cages used were large glass battery jars covered with cheesecloth tops, which were held in place by rubber bands. In cage *a* (Pl. II, fig. 1) are shown the racks in which the codling-moth larvæ have spun their cocoons. The details of these racks are illustrated in Plate II, figure 2, and described on page 4. Pupation is recorded daily and after the moths emerge the length of the pupal stage is computed. The moths are transferred daily from cages similar to cage *a* (Pl. II, fig. 1), and confined within cages like cage *b* (Pl. II, fig. 1). The bottom of cage *b* is covered with 3 inches of moist sand and contains fresh apple foliage and a sponge moistened with a sugar solution. The moths deposit their eggs upon the foliage, which is removed each day and the number of eggs recorded. The following data are obtained from cage *b*: (1) Days before egg deposition; (2) time of egg deposition; (3) length of oviposition period; (4) total number of eggs; (5) average number of eggs per female; (6) length of life of male and female moths.

In order to prevent curling, the leaves are placed between two pieces of wire screen until the leaves dry—cage *c* (Pl. II, fig. 1). They are then removed from cage *c* to cage *d* (Pl. II, fig. 1), in which cage the embryological changes and incubation periods are noted. Upon hatching the larvæ are transferred to cage *e* (Pl. II, fig. 1). This cage contains apples placed within a wire container and also the racks in which the larvæ spin their cocoons.

Since the time of entering the fruit is known and since the time of leaving is found by a daily examination of the cocoon racks, the length of the feeding period is thus established. By following the

successive stages of the codling moth through the series of five cages the life cycle is readily ascertained.

It should be explained here that each table is a unit in itself. Successive tables are not necessarily continuations of the life history of all of the same individuals. For example, it will be noted that Table I is a record of the time of pupation of 753 wintering larvæ and that Table II includes observations on the length of the pupal stage of but 483 of these individuals. Differences of this character may be due to natural or artificial causes, such as to death, to accidental injury, to parasites, to the removal of specimens for other purposes, and to accidental escape of the moths during examination.

WINTERING LARVÆ.

The wintering larvæ, as stated in the definition of terms, comprise first and second brood larvæ. These larvæ winter naturally in cocoons (Pl. I, fig. 1), usually beneath the loose bark of trees, in decayed wood, or in other similarly protected places on or about the tree. The larvæ are inactive until spring, when they remodel their cocoons, so as to furnish exit tubes for the moths. (See Pl. I, fig. 2.) The exit tube, which varies in length according to the exigency, assists the moth in successfully emerging from the cocoon.

The codling-moth larvæ used at the laboratory were collected early in the spring of 1913. These larvæ were secured from cider mills where they had spun up beneath the flooring and in other concealed places. The larvæ were then allowed to form new cocoons in racks such as are shown in the illustration (Pl. II, fig. 2).

These racks consist of two strips of soft wood, to the lower of which three narrow crosspieces are glued—one at each end and one in the middle. A thin piece of mica is then placed between these crosspieces and the top strip and the whole is held together by two clamps. This makes it possible to remove the top strip and to observe the specimens through the mica. Referring to the illustration, it will be seen that there are artificial cells or compartments. The walls of these were first outlined with a little glue over which sawdust was sprinkled. Although more than one larva frequently spins up within the same chamber the artificial barriers serve to keep the larvæ somewhat separated. Such separation facilitates the recording of the observations.

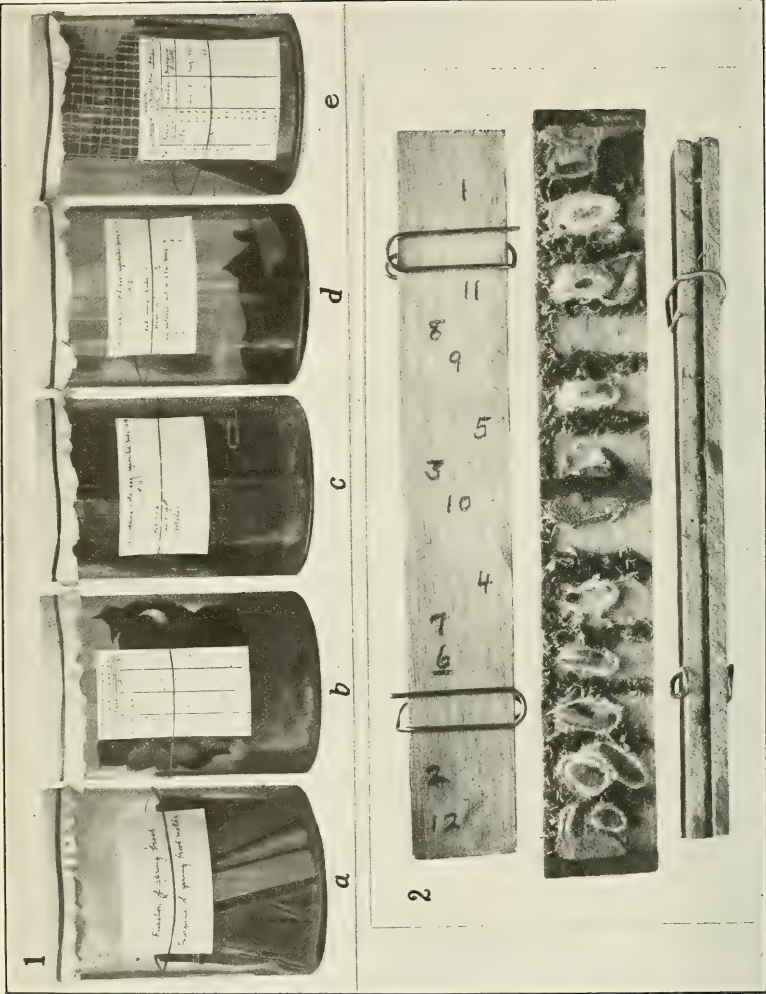
SPRING BROOD OF PUPÆ.

Time of pupation.—Daily observations of the wintering larvæ were taken and as each larva pupated its number was recorded upon the rack directly below the pupa. (Pl. II, fig. 2.) In Table I is shown



CHART ILLUSTRATING THE LIFE HISTORY OF THE CODLING MOTH IN MAINE.

FIG. 1.—Overwintering larva in cocoon. FIG. 2.—Cocoons remodeled by overwintering larvae to form exit tubes. The upper cocoon contains a spring-brood pupa; the lower, a pupal skin from which the moth emerged. FIG. 3.—A spring-brood moth. FIG. 4.—A spring-brood moth ovipositing on leaf, showing first-brood eggs. FIG. 5.—A wormy apple containing a first-brood larva. FIG. 6.—Cocoons of first-brood larvae, one of which transformed to pupa. FIG. 7.—First-brood moth ovipositing on leaf, showing second-brood eggs. FIG. 8.—An apple showing where a second-brood larva entered the side. Time to spray, as soon as petals drop. Too late to spray, calyx cup closed. (Original.)



APPARATUS EMPLOYED IN THE REARING OF THE CODLING MOTH IN MAINE.

FIG. 1.—a, Pupation and moth emergence cage; b, oviposition cage; c, leaf-pressing cage; d, incubation cage; e, feeding cage. FIG. 2.—Cocooning rack (three views) in which the larvae spin their cocoons and pupate. (Original.)

the time of pupation of 753 overwintering larvæ. It will be noted that the first larva pupated May 5, while the last larva under observation did not pupate until July 7. Hence spring-brood pupation extended over a period of about two months. The maximum

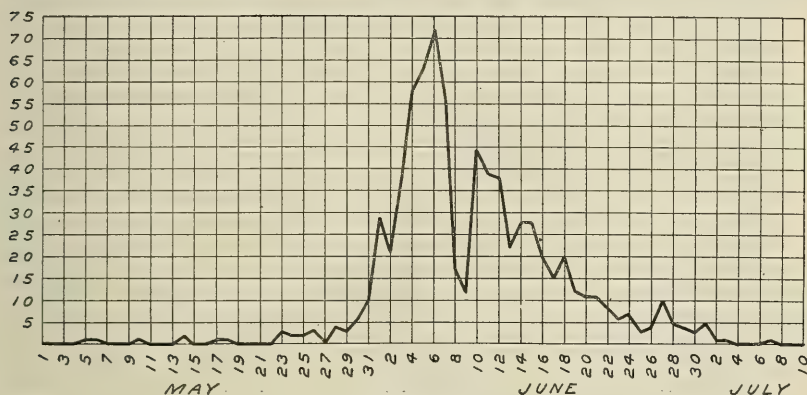


FIG. 1.—Diagram showing pupation of the spring brood of the codling moth in 1913 at Winthrop, Me. (Original.)

time of pupation was June 6, when 72 larvæ transformed. The greater part of the larvæ pupated during the first half of June. (See fig. 1.)

TABLE I.—Time of pupation of overwintering larvæ, Winthrop, Me., 1913.

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
May 5	1	May 31	10	June 13	22	June 26	4
May 6	1	June 1	29	June 14	28	June 27	10
May 10	1	June 2	21	June 15	28	June 28	5
May 14	2	June 3	38	June 16	20	June 29	4
May 17	1	June 4	58	June 17	15	June 30	3
May 18	1	June 5	63	June 18	20	July 1	5
May 23	3	June 6	72	June 19	12	July 2	1
May 24	2	June 7	56	June 20	11	July 3	1
May 25	2	June 8	17	June 21	11	July 7	1
May 26	3	June 9	12	June 22	9		
May 28	4	June 10	44	June 23	6		
May 29	3	June 11	39	June 24	7	Total ..	753
May 30	6	June 12	38	June 25	3		

Length of the pupal stage.—The average length of the pupal stage of 483 individuals, as recorded in Table II, was found to be 19.03 days; maximum, 44 days; minimum, 9 days. By reference to this table it will be seen that as the season advanced the length of the pupal stage was gradually shortened, due to higher average daily temperatures.

Time of egg deposition.—As will be seen in Table IV, the first eggs of the spring-brood moths were laid on June 22, while the last oviposition occurred July 30. Hence the period of oviposition was approximately 1 month. The average number of days from the time of emergence to the time of first oviposition was 4.086 days; maximum, 14 days; minimum, 1 day. The average duration of the oviposition period was 14.086 days; maximum, 26 days; minimum, 1 day. The average number of days from the date of moth emergence to the last date of oviposition was 16.739 days; maximum, 27 days; minimum, 6 days.

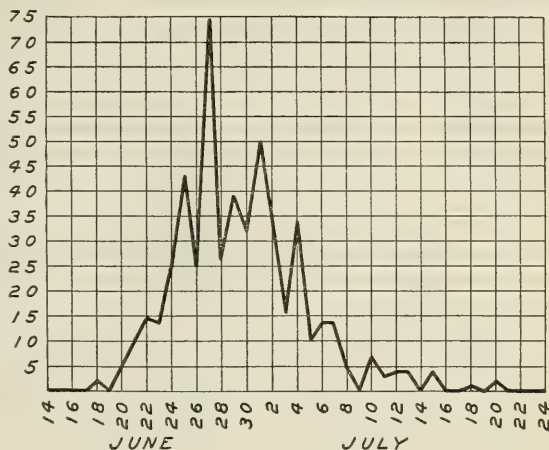


FIG. 2.—Diagram showing emergence of the spring brood of moths of the codling moth in 1913 at Winthrop, Me. (Original.)

TABLE IV.—Oviposition by moths of the spring brood in rearing cages, Winthrop, Me., 1913.

Cage No.	Number of moths.	Sex.		Date of—			Number of days—		
		♂	♀	Emergence of moths.	First oviposition.	Last oviposition.	Before oviposition.	Of oviposition.	From date of emergence to last oviposition.
1	2	9	8	June 18	June 22	July 7			
	5			June 20					
	10			June 21					
2	13	9	4	June 22	June 29	July 2	7	4	10
3	13	9	4	June 23	do.	July 3	6	5	10
4	19	12	7	June 24	do.	July 9	5	11	15
5	41	16	25	June 25	June 27	do.	2	13	14
6	24	13	11	June 26	July 3	July 8	7	6	12
7	30	16	14	June 27	June 29	July 14	2	16	17
8	38	12	26	do.	do.	July 24	2	26	27
9	24	11	13	June 28	July 1	July 13	3	13	15
10	26	8	18	June 29	do.	July 22	2	22	23
11	25	14	11	June 30	July 2	July 23	2	22	23
12	25	10	15	July 1	July 3	July 27	2	25	26
13	18	7	11	do.	do.	July 22	2	20	21
14	31	16	15	July 2	July 4	do.	2	19	20
15	14	5	9	July 3	July 5	July 23	2	19	20
16	28	15	13	July 4	do.	July 22	1	18	18
17	9	6	3	July 5	July 6	do.	1	17	17
18	13	3	10	July 6	July 8	July 30	2	23	24
19	11	4	7	July 7	July 11	July 29	4	19	22
20	5	3	2	July 8	July 18	July 20	10	3	12
21	5	1	4	July 10	July 17	July 25	7	9	15
22	4	2	2	July 12	July 15	July 20	3	6	8
23	3	1	2	July 13	July 17	July 23	14	7	10
24	4	2	2	July 15	July 21	July 21	6	1	6
Number of male moths.....				204	Average.....		4.086	14.086	16.739
Number of female moths.....				236	Maximum.....		14	26	27
Total number of moths.....				440	Minimum.....		1	1	6

Number of eggs per female.—No attempt was made to isolate fertilized females for the purpose of securing individual egg-laying records. However, by dividing the number of eggs laid by the number of female moths the average was computed. In Table IV it will be seen that 236 female moths were confined with 204 males in 24 cages. A few eggs were laid upon the sides of the cages, but these were not included in the computation. The number of eggs, exclusive of those laid upon glass, was 7,546, which number when divided by 236 gives an average of 31.974 eggs per female.

Length of life of moths.—Observations on the length of the life of 191 male moths and 229 female moths are shown in Table V. The average life of the male moth was 10.685 days; of the female, 12.253 days. Maximum number of days for male moth 34, for female 38; minimum number of days for male moth 2, for female 2.

TABLE V.—*Length of life of male and female moths of the spring brood in captivity; summary of records of 420 individual moths, Winthrop, Me., 1913.*

Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
<i>Days.</i>		<i>Days.</i>		<i>Days.</i>		<i>Days.</i>	
2	3	2	1	22	2	22	1
3	7	3	5	23	2	23	5
4	5	4	4	24	0	24	3
5	15	5	12	25	1	25	2
6	15	6	11	26	0	26	1
7	20	7	18	27	2	27	1
8	22	8	13	28	0	28	2
9	24	9	24	29	0	29	2
10	13	10	20	30	1	30	0
11	5	11	20	31	2	31	0
12	7	12	15	32	0	32	2
13	6	13	3	33	0	33	0
14	9	14	19	34	2	34	0
15	5	15	10	35	0	35	0
16	6	16	9	36	0	36	0
17	4	17	6	37	0	37	0
18	1	18	5	38	0	38	1
19	5	19	3				
20	4	20	7		191		229
21	3	21	4				

Average length of life of male moths, 10.685 days; female moths, 12.253 days.

Maximum length of life of male moths, 34 days; female moths, 38 days.

Minimum length of life of male moths, 2 days; female moths, 2 days.

THE FIRST GENERATION.

FIRST BROOD OF EGGS.

Length of incubation.—During the period of oviposition a record of 7,546 eggs was kept. Of this number 7,493 (99.29 per cent) hatched. The average number of days from the time of oviposition to the appearance of the red ring was 2.507; maximum, 5 days; minimum, 2 days. The average time elapsing from the time of oviposition to the appearance of the black spot was 5.580 days; maximum, 7 days; minimum, 4 days. The average incubation period was 8.874 days; maximum, 10 days; minimum, 6 days. The results are given in Table VI.

TABLE VI.—Length of incubation of first brood of eggs, Winthrop, Me., 1913.

No. of observation.	Number of eggs.	Date—				Appearance of—		Incubation period.	Number dead.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.		
1	-----	June 22	June 26	June 29	July 1	Days. 4	Days. 7	Days. 9	-----
2	1	June 24	June 27	do	do	3	5	7	-----
3	1	do	do	do	July 2	-----	-----	8	-----
4	11	June 26	June 28	July 1	July 3	2	5	7	-----
5	1	do	do	do	July 4	-----	-----	8	-----
6	10	June 27	June 29	July 2	July 3	2	5	6	-----
7	61	do	do	do	July 4	-----	-----	7	1
8	80	June 28	July 1	July 3	do	3	5	6	-----
9	37	do	do	do	July 5	-----	-----	7	-----
10	165	June 29	July 2	July 4	do	3	5	6	-----
11	40	do	do	do	July 6	-----	-----	7	-----
12	108	June 30	July 3	July 5	do	3	5	6	-----
13	10	do	do	do	July 7	-----	-----	7	-----
14	504	July 1	July 3	July 5	do	2	4	6	-----
15	31	do	do	do	July 8	-----	-----	7	-----
16	25	do	do	do	July 9	-----	-----	8	-----
17	65	July 2	July 4	July 6	July 8	2	4	6	-----
18	730	do	do	do	July 9	-----	-----	7	-----
19	20	do	do	do	July 10	-----	-----	8	-----
20	716	July 3	July 5	July 7	do	2	4	7	-----
21	46	do	do	do	July 11	-----	-----	8	19
22	27	July 4	July 7	July 10	do	3	6	7	-----
23	725	do	do	do	July 12	-----	-----	8	-----
24	15	do	do	do	July 13	-----	-----	9	4
25	1,040	July 5	July 8	July 12	do	3	7	8	-----
26	21	do	do	do	July 14	-----	-----	9	5
27	344	July 6	July 10	July 13	do	4	7	8	-----
28	274	do	do	do	July 15	-----	-----	9	-----
29	19	do	do	do	July 16	-----	-----	10	3
30	47	July 7	July 10	July 13	July 15	3	6	8	-----
31	9	do	do	do	July 16	-----	-----	9	-----
32	1	do	do	do	July 17	-----	-----	10	-----
33	153	July 8	July 10	July 14	July 16	2	6	8	-----
34	220	do	do	do	July 17	-----	-----	9	-----
35	169	July 9	July 11	July 15	do	2	6	8	-----
36	17	do	do	do	July 18	-----	-----	9	5
37	21	July 10	July 12	July 15	do	2	5	8	-----
38	4	do	do	do	July 19	-----	-----	9	-----
39	326	July 11	July 13	July 16	do	2	5	8	-----
40	5	do	do	do	July 20	-----	-----	9	-----
41	414	July 12	July 14	July 18	do	2	6	8	-----
42	17	do	do	do	July 21	-----	-----	9	6
43	123	July 13	July 15	July 19	July 20	2	6	7	-----
44	47	do	do	do	July 21	-----	-----	8	-----
45	9	do	do	do	July 22	-----	-----	9	1
46	59	July 14	July 17	July 20	do	3	6	8	-----
47	2	do	do	do	July 23	-----	-----	9	1
48	54	July 15	July 17	July 21	July 22	2	6	7	-----
49	64	do	do	do	July 23	-----	-----	8	-----
50	173	July 16	July 18	July 22	do	2	6	7	-----
51	22	do	do	do	July 24	-----	-----	8	2
52	25	July 17	July 22	July 23	do	5	6	7	-----
53	129	do	do	do	July 25	-----	-----	8	-----
54	9	July 18	July 22	July 23	do	4	5	7	-----
55	15	do	do	do	July 26	-----	-----	8	1
56	10	July 19	July 22	July 24	July 25	3	5	6	-----
57	38	do	do	do	July 26	-----	-----	7	-----
58	50	July 20	July 23	July 25	July 27	3	5	7	-----
59	6	do	do	do	July 28	-----	-----	8	-----
60	35	July 21	July 24	July 27	do	3	6	7	-----
61	11	do	do	do	July 29	-----	-----	8	2
62	40	July 22	July 25	July 27	do	3	5	7	-----
63	7	do	do	do	July 30	-----	-----	8	-----
64	20	July 23	July 26	July 29	do	3	6	7	2
65	20	July 24	do	July 30	July 31	2	6	7	-----
66	14	July 25	July 27	do	Aug. 1	2	5	7	-----
67	1	do	do	do	Aug. 2	-----	-----	8	-----
68	8	July 26	July 28	Aug. 1	do	2	6	7	-----
69	2	do	do	do	Aug. 3	-----	-----	8	1
70	6	July 27	July 29	Aug. 2	do	2	6	7	-----
71	3	do	do	do	Aug. 4	-----	-----	8	-----
72	6	July 28	July 30	Aug. 2	do	2	5	7	-----
73	4	July 29	July 31	Aug. 4	Aug. 5	2	6	7	-----
74	3	do	do	do	Aug. 6	-----	-----	8	-----
75	1	Aug. 1	Aug. 4	Aug. 7	Aug. 9	3	6	8	-----
Average.....						2,507	5,580	8,874	53
Maximum.....						5	7	10	-----
Minimum.....						2	4	6	-----

25.925 days; maximum, 49 days; minimum, 16 days. The average feeding period for 140 male larvæ was 24.621 days; maximum, 46 days; minimum, 16 days. The average for 207 female larvæ was 26.371 days; maximum, 44 days; minimum, 19 days. Remainder of larvæ—sex undetermined.

TABLE X.—*Length of feeding period of wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1913.*

[Figures in parentheses () denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		16		19		20		21		22		23		24		25		26	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4.....	July 5										1			1					
8.....	July 6													3		2			
9.....	July 7							1		1		1	(1)	1		2			
18.....	July 8									1	1		2	1	2		2		
10.....	July 9													2		1			
39.....	July 10					1	1			1		3	4(1)	4	4	1	(1)	2	
13.....	July 11									2		1				2	1	1	
25.....	July 12							2	2			1	1	3		1	3	2	
13.....	July 13											1			2			1	
13.....	July 14					2		1		3		(1)			1	1	1(1)		
41.....	July 15			1	1	3	4	3	2	1	5	3	2	2	3(2)	1	1	(1)	2
6.....	July 16				1			2				(1)							
16.....	July 17									2			2	3			1		
22.....	July 19			1		4	1	3	3(1)	1	2	1		1					
28.....	July 20	1			1				2	1	2	1	4	2(2)	1		2		
15.....	July 21							1				2	1	2	1		1		
12.....	July 23											2	1	2	3	1			
13.....	July 24									1		(1)	3		3	2	1		
14.....	July 25																		
11.....	July 26				(1)					1				1	2				
4.....	July 27																1		
16.....	July 28									1	1			1	2	1	1		
13.....	July 29					1		2		2		1	(1)	(1)				(2)	1
12.....	July 30							1		1	1					3		1	
2.....	July 31																		
2.....	Aug. 1																		
3.....	Aug. 3									1					(1)				
2.....	Aug. 4																		
5.....	Aug. 6																(1)	1	
1.....	Aug. 9														(1)				
390 ♂ and ♀.....		1	0	2	3	11	6	16	9	14	21	15	20	26	28	15	16	9	24
Sex undetermined.....						1		1				5		8		3		3	
Total.....		1		5		18		26		35		40		62		34		36	

TABLE X.—Length of feeding period of wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1913—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		27		28		29		30		31		32		33		34		35	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4.....	July 5	.....	1	.....	.....	1	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....
8.....	July 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....
9.....	July 7	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18.....	July 8	.....	.....	3	1(2)	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....
10.....	July 9	2	1(1)	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
39.....	July 10	.....	1	.....	3	1	1	(1)	4	.....	.....	1	.....	.....	.....	.....	1	.....	.....
13.....	July 11	.....	.....	1	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	2	.....	.....
25.....	July 12	(1)	1	1	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	(1)	.....	.....
13.....	July 13	.....	1	.....	.....	.....	.....	.....	.....	1	(1)	.....	.....	.....	.....	2	.....	.....	.....
13.....	July 14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
41.....	July 15	.....	.....	.....	.....	1	.....	.....	.....	1	.....	.....	.....	.....	.....	1	.....	.....	.....
6.....	July 16	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16.....	July 17	.....	.....	1(1)	2	.....	.....	.....	2	.....	1	.....	.....	.....	.....	1	.....	.....	.....
22.....	July 19	.....	.....	.....	.....	.....	.....	.....	1	.....	1	.....	.....	.....	.....	1	.....	(1)	.....
28.....	July 20	.....	2	1	.....	.....	.....	.....	2	1	.....	.....	.....	.....	.....	.....	.....	(1)	.....
15.....	July 21	(1)	1	(1)	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....
12.....	July 23	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....
13.....	July 24	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	1
14.....	July 25	.....	.....	3	4	.....	.....	1	1	.....	.....	1	.....	.....	1	.....	.....	.....	.....
11.....	July 26	.....	.....	.....	.....	.....	.....	1	1	1	.....	1	.....	.....	.....	.....	.....	.....	1
4.....	July 27	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16.....	July 28	.....	.....	.....	.....	2	.....	.....	.....	.....	2	.....	.....	1	.....	1	.....	.....	.....
13.....	July 29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12.....	July 30	.....	.....	1	.....	1	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....
2.....	July 31	.....	.....	.....	(1)	.....	.....	.....	.....	.....	.....	(1)	.....	.....	.....	.....	.....	.....	.....
2.....	Aug. 1	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	(1)	.....	.....	.....	.....	.....	.....	.....
3.....	Aug. 3	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	(1)	.....	.....	.....	.....	.....	.....
2.....	Aug. 4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5.....	Aug. 6	.....	.....	.....	.....	1	.....	.....	.....	.....	(1)	.....	.....	(1)	.....	.....	.....	.....	.....
1.....	Aug. 9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
390 ♂ and ♀.....		3	10	11	15	2	8	2	13	4	7	3	2	3	4	0	12	0	2
Sex undetermined.....		3	.....	4	.....	1	.....	1	.....	2	.....	2	.....	1	.....	.....	.....	3	.....
Total.....		16	.....	30	.....	11	.....	16	.....	13	.....	7	.....	8	.....	12	.....	5	.....

TABLE X.—Length of feeding period of wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1913—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		36		37		38		39		40		43		44		46	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4	July 5																
8	July 6																
9	July 7					(1)											
18	July 8																
10	July 9																
39	July 10					(1)								1			
13	July 11			(1)													
25	July 12									1							
13	July 13																
13	July 14																
41	July 15		1														
6	July 16																
16	July 17																
22	July 19																
28	July 20																
15	July 21																
12	July 23																
13	July 24																
14	July 25	(1)			1												
11	July 26							(1)									
4	July 27				1												
16	July 28																
13	July 29				1			1								1	
12	July 30						1	1							1		
2	July 31																
2	Aug. 1																
3	Aug. 3																
2	Aug. 4																
5	Aug. 6																
1	Aug. 9																
390 ♂ and ♀		0	1	0	3	0	1	1	0	1	0	0	1	0	1	1	0
Sex undetermined		1		1		2		1									
Total		2		4		3		2		1		1		1		1	

Average feeding period, 390 male and female larvæ, 25.925 days; 140 male larvæ, 24.621 days; 207 female larvæ, 26.371 days.

Maximum feeding period, 390 male and female larvæ, 49 days; 140 male larvæ, 46 days; 207 female larvæ, 44 days.

Minimum feeding period, 390 male and female larvæ, 16 days; 140 male larvæ, 16 days; 207 female larvæ, 19 days.

Length of the feeding period of wintering first-brood larvæ (watered stock-jar method).—As shown in Table XI, the average feeding period of 260 male and female larvæ was 26.569 days; maximum, 41 days; minimum, 19 days. The average for 111 male larvæ was 26.315 days; maximum, 40 days; minimum, 19 days. The average feeding period for 123 female larvæ was 26.463 days; maximum, 41 days; minimum, 20 days. Remainder of larvæ—sex undetermined.

TABLE XI.—Length of feeding period of wintering larvæ of the first brood, watered stock-jar method, Winthrop, Me., 1913.

[Figures in parentheses () denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		19		20		21		22		23		24		25		26	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4.....	July 7																
17.....	July 8											1				2	(2)
16.....	July 9											1	(1)			1	1
11.....	July 10							1		1	(2)	1				1	2
13.....	July 11							2		4	4				2		
26.....	July 12							1	(1)	3				5	1(1)	4	2
10.....	July 13			2		1				2	1			1		1	1
12.....	July 14							1	(1)		(1)	2		2		1	2
19.....	July 15	1		2		3	1	3	1		1	1				1	3
17.....	July 16							1		2	2	1		1		1	3
18.....	July 17					1				1	1						
9.....	July 18									2				1	2		1
18.....	July 20					1			2			2	1	2			1
15.....	July 21							3									
8.....	July 22							2	2		1					1	1
15.....	July 23															1	1
15.....	July 24											1		1	6	1	1
7.....	July 25															1	4
7.....	July 26							1		1				1		1	
3.....	July 27							1		1				1			
260 ♂ and ♀.....		1	0	4	0	6	1	8	12	10	14	5	9	11	10	22	23
Sex undetermined.....										2		3		2		2	
Total.....		1		4		7		20		26		17		23		47	

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		27		28		29		30		31		32		33			
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4.....	July 7			2		1	1										
17.....	July 8			2	1(2)			1	2							1	1
16.....	July 9			2	3			1	2	(1)							
11.....	July 10	1	1					1									
13.....	July 11	(1)															
26.....	July 12	(1)	2			(1)	3					(1)					
10.....	July 13		1														
12.....	July 14		1	1													
19.....	July 15																
17.....	July 16		1		1	(1)	1			1							
18.....	July 17	1		2				3				2	2	1	1		
9.....	July 18					1	1			1							
18.....	July 20	1	1		1	1	1	1	(2)	1							
15.....	July 21	3(2)	2		2							(1)	2				
8.....	July 22	(1)															
15.....	July 23	2	2	1		1	1			2							
15.....	July 24			2	2(1)			(1)									
7.....	July 25						1							1			
7.....	July 26			2								1					
3.....	July 27																
260 ♂ and ♀.....		8	15	10	11	4	9	6	4	4	4	4	4	4	2	2	
Sex undetermined.....				5	3	2		3		1		2					
Total.....				28	24	15		13		9		10		4			

TABLE XI.—Length of feeding period of wintering larvæ of the first brood, watered stock-jar method, Winthrop, Me., 1913—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.													
		34		35		36		37		38		40		41	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4.....	July 7														
17.....	July 8			1						1					
16.....	July 9	1		1								1			
11.....	July 10														
13.....	July 11														
26.....	July 12														
10.....	July 13														
12.....	July 14														
19.....	July 15														
17.....	July 16														
18.....	July 17					1		1		1					1
9.....	July 18														
18.....	July 20														
15.....	July 21														
8.....	July 22														
15.....	July 23	2		1								(1)			
15.....	July 24														
7.....	July 25														
7.....	July 26														
3.....	July 27														
260 ♂ and ♀.....		3		2		1		1		2		1			1
Sex undetermined.....												1			
Total.....		3		2		1		1		2		2			1

Average length of feeding period, 260 male and female larvæ, 26.569 days; 111 male larvæ, 26.315 days; 123 female larvæ, 26.463 days.

Maximum length of feeding period, 260 male and female larvæ, 41 days; 111 male larvæ, 40 days; 123 female larvæ, 41 days.

Minimum length of feeding period, 260 male and female larvæ, 19 days; 111 male larvæ, 19 days; 123 female larvæ, 20 days.

Length of the feeding period of wintering first-brood larvæ (bagged-fruit method).—Table XII shows that the average feeding period of 236 male and female larvæ was 32.572 days; maximum, 49 days; minimum, 19 days. The average for 93 male larvæ was 29.182 days; maximum, 49 days; minimum, 24 days. The average for 126 female larvæ was 35.492 days; maximum, 46 days; minimum, 19 days. The sex of the remainder of the larvæ was undetermined.

TABLE XII.—Length of feeding period of wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1913.

[Figures in parentheses () denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		19		23		24		25		26		27		28		29		30	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	July 3										1								
17	July 4									2			1		2	3	1		
10	July 5										1	1			1	1			2
11	July 6									1		1	1		(1)	2	1		(1)
22	July 7							1		6	4	4	1		(1)	2	2		1
19	July 8					1		1		1	2			3(2)	3				3
29	July 9				1			3	3		2	1	5	2	3			(2)	2
15	July 10			1	3	1(1)		1		1	1		3		1	1			1
12	July 11							1				1			2		2		1
10	July 12									1	1			1				1	1
24	July 13				1	(1)		1	1	2	2(1)		1	2		4	1(1)		
11	July 14							1	1	1		1	1		1			2	
10	July 15													1	1				
4	July 16														1				
15	July 17											1					2		
8	July 20		1												1	1			
11	July 22							2	1			2	(1)						
7	July 23							1					1				1		
236 ♂ and ♀			1	0	1	5	2	8	8	15	12	14	16	10	13	9	14	7	11
Sex undetermined						2				1		1		2		3		3	
Total			1		1	9		16		28		31		25		26		21	

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																
		31		32		33		34		35		36		37		39		
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
1.....	July 3																	
17.....	July 4			2		1		1					1		1			
10.....	July 5			2		(1)											1	
11.....	July 6	1																
22.....	July 7																	
19.....	July 8	1			2													
29.....	July 9		1	3											1			
15.....	July 10																	
12.....	July 11		2		2					(1)								
10.....	July 12			1			3						1					
24.....	July 13			2		1		1			1		1					
11.....	July 14			1	2	1												
10.....	July 15		1		2			1	1		1				1			
4.....	July 16				1													
15.....	July 17			1	2						1	1	3	(1)				
8.....	July 20				1		1							1				
11.....	July 22	(2)	3															
7.....	July 23	1								2					1			
236 ♂ and ♀.....		3	9	10	12	2	4	3	1		5	1	6		1	4		1
Sex undetermined.....		2				1				1					1			
Total.....		14		22		7		4		6		7		6		1		

TABLE XII.—Length of feeding period of wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1913—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		40		41		42		43		44		46		47		49	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1.....	July 3																
17.....	July 4							2									
10.....	July 5																
11.....	July 6				1												
22.....	July 7																
19.....	July 8																
29.....	July 9																
15.....	July 10																
12.....	July 11																
10.....	July 12																
24.....	July 13	1															
11.....	July 14																
10.....	July 15					1											
4.....	July 16			1		1										1	
15.....	July 17									1		1	1				
8.....	July 20																
11.....	July 22																
7.....	July 23																
236 ♂ and ♀.....		1		2		2	2			1		1	1	1		1	
Sex undetermined.....																	
Total.....		1		2		2	2			1		1	1	1		1	

Average length of feeding period, 236 male and female larvæ, 32.572 days; 93 male larvæ, 29.182 days; 126 female larvæ, 35.492 days.

Maximum length of feeding period, 236 male and female larvæ, 49 days; 93 male larvæ, 49 days; 126 female larvæ, 46 days.

Minimum length of feeding period, 236 male and female larvæ, 19 days; 93 male larvæ, 24 days; 126 female larvæ, 19 days.

It will be noted that the larvæ which transform during the same season as hatched have, upon an average, a shorter feeding period than those which do not transform until the following spring. The average feeding period for 30 transforming larvæ of the first brood was 23.432 days; the average feeding period for 886 wintering larvæ of the first brood was 27.884 days. It will be further noted that in every instance, except one (Table VII), the average feeding period of the female larvæ was longer than that of the male. In the exception cited the result is not considered conclusive, owing to the small number of observations.

Larval life in the cocoon.—The time of making the cocoon is calculated from the time a transforming larva leaves the fruit until it has pupated. The average time consumed in constructing the cocoon was 6.566 days; maximum, 13 days; minimum, 2 days. (See Table XIII.)

TABLE XIII.—Length of the pupal stage of the first brood, Winthrop, Me., 1913.

No. of observation.	Date of—			Mak- ing of co- coon.	Pupal pe- riod.	No. of ob- serva- tion.	Date of—			Mak- ing of co- coon.	Pupal period.
	Leaving fruit.	Pupa- tion.	Emer- gence.				Leaving fruit.	Pupa- tion.	Emer- gence.		
				<i>Days.</i>	<i>Days.</i>					<i>Days.</i>	<i>Days.</i>
1	July 25	July 30	Aug. 11	5	12	16	July 31	Aug. 6	Aug. 23	6	17
2	July 26	do	Aug. 14	4	15	17	do	Aug. 8	Aug. 27	8	19
3	July 27	do	do	3	15	18	do	Aug. 9	Aug. 23	9	14
4	do	Aug. 1	Aug. 16	5	15	19	Aug. 2	Aug. 8	Aug. 27	6	19
5	July 28	Aug. 3	Aug. 17	6	14	20	do	Aug. 9	Aug. 24	7	15
6	July 29	do	do	5	14	21	Aug. 3	do	Aug. 23	6	14
7	do	do	do	5	14	22	do	Aug. 10	Aug. 25	7	15
8	July 30	do	do	4	14	23	do	Aug. 11	Aug. 26	8	15
9	do	Aug. 4	do	5	13	24	do	Aug. 15	Aug. 30	12	15
10	do	Aug. 5	Aug. 20	6	15	25	do	Aug. 16	Sept. 1	13	16
11	do	Aug. 7	Aug. 22	8	15	26	Aug. 5	Aug. 11	Aug. 26	6	15
12	do	Aug. 9	Aug. 26	10	17	27	Aug. 6	Aug. 13	Aug. 31	7	18
13	July 31	Aug. 4	Aug. 18	4	14	28	Aug. 7	Aug. 14	Aug. 29	7	15
14	do	Aug. 5	Aug. 19	5	14	29	Aug. 8	Aug. 10	Aug. 26	2	16
15	do	Aug. 6	do	6	13	30	Aug. 10	Aug. 22	Sept. 6	12	15
Average.....										6.566	15.066
Maximum.....										13	19
Minimum.....										2	12

FIRST BROOD OF PUPÆ OR SUMMER PUPÆ.

Time of pupation.—The earliest pupation of the first-brood larvæ occurred July 30, the latest August 22. (See Table XIII and fig. 3.)

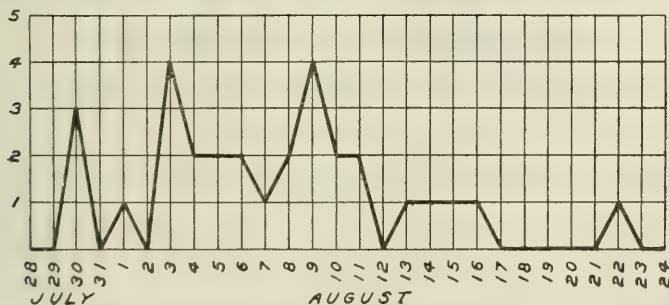


FIG. 3.—Diagram showing pupation of the first brood of the codling moth in 1913 at Winthrop, Me. (Original.)

Length of the pupal stage.—The average length of the first-brood pupal stage, as shown in Table XIII, was 15.066 days; maximum, 19 days; minimum, 12 days.

FIRST OR SUMMER BROOD OF MOTHS.

Time of emergence.—First-brood moth emergence commenced August 7, as shown in Table XIV. The last moth of the summer brood emerged September 6. As previously stated, the number of first-brood larvæ transforming in Maine is comparatively small, and hence the summer brood of moths is small. (See fig. 4.)

TABLE XIV.—*Time of emergence of moths of the first or summer brood, Winthrop, Me., 1913.*

Date of emergence.	Total emergence.	Date of emergence.	Total emergence.
Aug. 7	1	Aug. 23	4
9	3	24	2
11	1	25	1
13	3	26	4
16	1	27	2
17	5	31	2
18	2	Sept. 1	1
19	2	6	1
20	1		
			36

Time of oviposition.—The first eggs of the summer-brood moths were deposited August 15, the last were laid September 25. (See Table XV.)

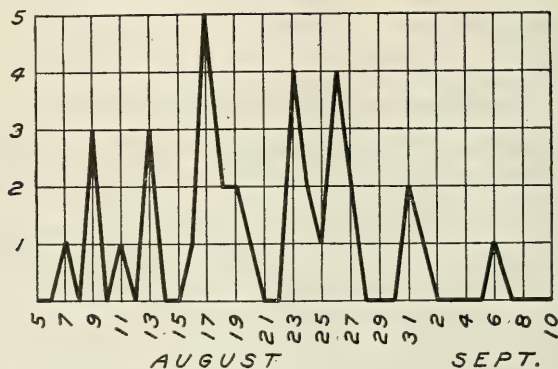


FIG. 4.—Diagram showing emergence of the first brood of moths of the codling moth in 1913 at Winthrop, Me. (Original.)

TABLE XV.—*Time of oviposition of the first or summer brood of moths, Winthrop, Me., 1913.*

CAGE NO. 1.

Date.	Number of moths emerged.	Eggs deposited.	Death of moths. ¹		Date.	Number of moths emerged.	Eggs deposited.	Death of moths. ¹	
			Male.	Female.				Male.	Female.
Aug. 7	1	-----	-----	-----	Aug. 19	-----	Eggs...	1	-----
9	3	-----	-----	-----	20	-----	-----	1	1
11	1	-----	-----	-----	25	-----	-----	1	-----
13	3	-----	-----	-----	26	-----	-----	1	1
15	-----	Eggs...	-----	-----	Sept. 3	-----	-----	-----	1
16	1	do...	-----	-----		9	-----	4	4
17	-----	do...	-----	-----					
18	-----	do...	-----	1					

¹ One moth escaped from cage No. 1, 2 from cage No. 2.

TABLE XV.—*Time of oviposition of the first or summer brood of moths, Winthrop, Me., 1913—Continued.*

CAGE NO. 2.

Date.	Number of moths emerged.	Eggs deposited.	Death of moths.		Date.	Number of moths emerged.	Eggs deposited.	Death of moths.	
			Male.	Female.				Male.	Female.
Aug. 17	5	.....	.....	.....	Sept. 4	.....	Eggs...	2	1
18	2	.....	.....	.....	5	.....	do...	.....	.....
19	2	.....	.....	.....	6	1	do...	.....	.....
20	1	.....	.....	.....	7	.....	do...	.....	2
21	.....	.....	.....	.....	8	.....	do...	.....	.....
22	.....	Eggs...	.....	.....	10	.....	do...	.....	2
23	4	do...	.....	.....	12	.....	do...	.....	1
24	2	do...	.....	1	14	.....	do...	1	1
25	1	do...	.....	.....	15	.....	Eggs...	.....	.....
26	4	do...	.....	1	20	.....	.....	1	.....
27	2	do...	.....	.....	22	.....	Eggs...	.....	.....
28	.....	do...	.....	.....	25	.....	do...	.....	.....
29	.....	do...	.....	.....	26	.....	.....	1	.....
30	.....	do...	.....	2	27	.....	.....	1	1
31	2	do...	2	1	28	.....	.....	1	.....
Sept. 1	1	do...	1	2	.....	.....	.....	.....	.....
2	.....	do...	.....	.....	.....	27	.....	10	15
3	.....	do...	.....	.....	.....	.....	.....	.....	.....

Number of eggs per first-brood female moth.—This data was obtained by dividing the total number of second-brood eggs (1,013) by the total number of female moths kept in confinement. These figures show that the average number of eggs per female was 53.316.

LENGTH OF LIFE CYCLE OF THE FIRST GENERATION.

In view of the fact that three methods of taking codling-moth feeding records were used, it became necessary to give the life-cycle results in three separate tables—Tables XVI, XVII, and XVIII. These tables include the life cycle of the insect from the time of egg deposition to the emergence of the moth and, as recorded therein, the life cycle according to the stock-jar method was 47.818 days; watered stock-jar method, 53.500 days; bagged-fruit method, 54 days. The complete life cycle extends from the time of the deposition of the egg of one generation to the deposition of the egg of the next generation. Hence, in order to get the number of days for the complete life cycle the time elapsing from the emergence of the moth to the first oviposition—approximately 4 days—should be added to the above figures.

TABLE XVI.—*Life cycle of the first generation of the codling moth, as observed by rearing at Winthrop, Me., 1913, stock-jar feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupa-tion.	Emer-gence of moth.	Hatch-ing.	Feed-ing.	Mak-ing of cocoon.	Pupal period.	Life cycle. ¹
1	June 30	July 6	July 30 ♂	Aug. 7	Aug. 22	6	24	8	15	53
2	July 1	July 7	July 25	July 30	Aug. 11	6	18	5	12	41
3	do	do	July 26	do	Aug. 14	6	19	4	15	44
4	do	do	July 27	Aug. 1	Aug. 16	6	20	5	15	46
5	do	do	July 28 ♂	Aug. 3	Aug. 17	6	21	6	14	47
6	do	do	July 29 ♂	do	do	6	22	5	14	47
7	do	do	July 31 ♀	Aug. 6	Aug. 19	6	24	6	13	49
8	July 3	July 10	July 30 ♀	Aug. 5	Aug. 20	7	20	6	15	48
9	do	do	July 31 ♀	Aug. 9	Aug. 23	7	21	9	14	51
10	July 7	July 15	Aug. 3 ♀	Aug. 15	Aug. 30	8	19	12	15	54
11	July 11	July 19	Aug. 5 ♀	Aug. 11	Aug. 26	8	17	6	15	46
Average.....						6.545	20.454	6.545	14.272	47.818
Maximum.....						8	24	12	15	54
Minimum.....						6	17	4	12	41

¹ Add 4 days for complete life cycle.TABLE XVII.—*Life cycle of the first generation of the codling moth, as observed by rearing at Winthrop, Me., 1913, watered stock-jar feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupa-tion.	Emer-gence of moth.	Hatch-ing.	Feed-ing.	Mak-ing of cocoon.	Pupal period.	Life cycle. ¹
1	July 1	July 7	July 29 ²	Aug. 3	Aug. 17	6	22	5	14	47
2	do	do	July 30 ²	do	do	6	23	4	14	47
3	July 2	July 8	Aug. 3 ³	Aug. 9	Aug. 23	6	26	6	14	52
4	do	do	Aug. 8	Aug. 10	Aug. 26	6	31	2	16	55
5	July 3	July 10	Aug. 6 ²	Aug. 13	Aug. 31	7	27	7	18	59
6	July 4	July 11	Aug. 3 ³	Aug. 16	Sept. 1	7	23	13	16	59
7	July 5	July 12	Aug. 2 ²	Aug. 9	Aug. 24	7	21	7	15	50
8	do	do	Aug. 3 ²	Aug. 10	Aug. 25	7	22	7	15	51
9	do	do	Aug. 7 ³	Aug. 14	Aug. 29	7	26	7	15	55
10	July 8	July 16	Aug. 10 ³	Aug. 22	Sept. 6	8	25	12	15	60
Average.....						6.7	24.6	7	15.2	53.5
Maximum.....						8	31	13	18	60
Minimum.....						6	21	2	14	47

¹ Add 4 days for complete life cycle.² Male.³ Female.

TABLE XVIII.—*Life cycle of the first generation of the codling moth, as observed by rearing at Winthrop, Me., 1913, bagged-fruit feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupation.	Emergence of moth.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle. ¹
1	June 26	July 3	July 27	July 30	Aug. 14	7	24	3	15	49
2	June 28	July 4	July 30 ²	Aug. 9	Aug. 26	6	26	10	17	59
3	...do....	...do....	July 31 ²	Aug. 8	Aug. 27	6	27	8	19	60
4	...do....	...do....	...do. ³	Aug. 6	Aug. 23	6	27	6	17	56
5	...do....	...do....	Aug. 3 ²	Aug. 11	Aug. 26	6	30	8	15	59
6	June 29	July 5	July 30 ³	Aug. 4	Aug. 17	6	25	5	13	49
7	...do....	...do....	Aug. 2 ²	Aug. 8	Aug. 27	6	28	6	19	59
8	July 1	July 7	July 31 ³	Aug. 4	Aug. 18	6	24	4	14	48
9	July 3	July 10	...do. ³	Aug. 5	Aug. 19	7	21	5	14	47
Average.....						6.222	25.777	6.111	15.888	54
Maximum.....						7	30	10	19	60
Minimum.....						6	21	3	13	47

¹ Add 4 days for complete life cycle.² Male.³ Female.

As shown in Table XIX, which is a summary of Tables XVI, XVII, and XVIII, the average of the life cycles was 51.566 days. The complete life cycle would be about 55 to 56 days.

TABLE XIX.—*Summary of the life cycle of the first generation of the codling moth, Winthrop, Me., 1913.*

	Number of observations.	Larval feeding method.	Days for—				
			Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle. ¹
Average life cycle.....	11	A	6.545	20.454	6.545	14.272	47.818
Do.....	10	B	6.700	24.600	7.060	15.200	53.500
Do.....	9	C	6.222	25.777	6.111	15.888	54.000
Average of all life cycles.....	30	A+B+C	6.499	23.432	6.566	15.066	51.566

¹ Add 4 days for complete life cycle. *

A, stock-jar method; B, watered stock-jar method; C, bagged-fruit method.

THE SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation.—Observations on the period of incubation extended from August 15, when the first eggs of the second brood were deposited, until October 15, when the last of the eggs of this brood hatched. A total of 1,013 eggs were laid, of which number 972 (95.9 per cent) hatched. The average incubation period was 11.862 days; maximum, 23 days; minimum, 7 days. The average time for the appearance of the red ring was 2.884 days; maximum, 7 days; minimum, 1 day. The average time for the appearance of the black spot was 9.069 days; maximum, 18 days; minimum, 5 days. The incubation observations are recorded in Table XX.

TABLE XX.—*Length of incubation of second brood of eggs, Winthrop, Me., 1913.*

No. of observation.	Number of eggs.	Date—				Appearance of—		Incubation period.	Number dead.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.		
						Days.	Days.	Days.	
1	10	Aug. 15	Aug. 16	Aug. 21	Aug. 23	1	6	8	2
2	28	Aug. 16	Aug. 17	Aug. 22	Aug. 24	1	6	8	
3	10	do.	do.	do.	Aug. 25			9	
4	15	Aug. 17	Aug. 19	Aug. 24	do.	2	7	8	
5	48	do.	do.	do.	Aug. 26			9	14
6	17	Aug. 18	Aug. 20	Aug. 25	Aug. 27	2	7	9	
7	31	do.	do.	do.	Aug. 28			10	
8	10	do.	do.	do.	Aug. 29			11	2
9	7	Aug. 19	Aug. 22	Aug. 26	do.	3	7	10	
10	2	do.	do.	do.	Aug. 30			11	1
11	5	Aug. 22	Aug. 25	Aug. 30	Sept. 1	3	8	10	
12	86	Aug. 23	do.	do.	do.	2	7	9	
13	3	do.	do.	do.	Sept. 2			10	
14	26	Aug. 24	Aug. 27	Sept. 1	do.	3	8	9	
15	8	do.	do.	do.	Sept. 3			10	
16	1	Aug. 25	Aug. 28	Sept. 1	Sept. 2	3	7	8	
17	3	do.	do.	do.	Sept. 3			9	
18	16	Aug. 26	Aug. 29	Sept. 1	do.	3	6	8	
19	16	Aug. 27	Aug. 31	Sept. 2	do.	4	6	7	
20	42	do.	do.	do.	Sept. 4			8	5
21	36	Aug. 28	Aug. 31	Sept. 3	do.	3	6	7	
22	9	do.	do.	do.	Sept. 5			8	1
23									
24	5	Aug. 30	Sept. 2	Sept. 4	Sept. 6	3	5	7	
25	28	do.	do.	do.	Sept. 7			8	
26	4	do.	do.	do.	Sept. 8			9	
27	61	Aug. 31	Sept. 3	Sept. 6	do.	3	6	8	
28	9	do.	do.	do.	Sept. 9			9	
29	22	do.	do.	do.	Sept. 10			10	1
30	30	Sept. 1	Sept. 3	Sept. 8	do.	2	7	9	
31	15	do.	do.	do.	Sept. 11			10	
32	12	do.	do.	do.	Sept. 12			11	5
33	31	Sept. 2	Sept. 4	Sept. 10	Sept. 14	2	8	12	
34	15	do.	do.	do.	Sept. 15			13	
35	11	do.	do.	do.	Sept. 16			14	2
36	109	Sept. 3	Sept. 6	Sept. 15	Sept. 18	3	12	15	
37	16	do.	do.	do.	Sept. 19			16	
38	1	do.	do.	do.	Sept. 20			17	
39	4	do.	do.	do.	Sept. 21			18	3
40	24	Sept. 4	Sept. 7	Sept. 17	do.	3	13	17	
41	2	do.	do.	do.	Sept. 22			18	
42	48	Sept. 5	Sept. 8	Sept. 18	do.	3	13	17	
43	16	do.	do.	do.	Sept. 23			18	
44	5	do.	do.	do.	Sept. 24			19	
45	6	Sept. 6	Sept. 10	Sept. 22	do.	4	16	18	
46	2	do.	do.	do.	Sept. 25			19	
47	27	Sept. 7	Sept. 12	Sept. 23	Sept. 26	5	16	19	
48	3	do.	do.	do.	Sept. 27			20	
49	32	Sept. 8	Sept. 13	Sept. 26	Sept. 29	5	18	21	
50	7	do.	do.	do.	Sept. 30			22	5
51	8	Sept. 10	Sept. 17	Sept. 28	Oct. 2	7	18	22	
52	2	do.	do.	do.	Oct. 3			23	
53	4	Sept. 12	Sept. 18	Sept. 29	do.	6	17	21	
54	1	do.	do.	do.	Oct. 4			22	
55	8	Sept. 15	Sept. 20	Sept. 30	do.	5	15	19	
56	4	Sept. 22	Sept. 26	Oct. 6	Oct. 8	4	14	16	
57	4	do.	do.	do.	Oct. 9			17	
58	2	do.	do.	do.	Oct. 10			18	
59	6	Sept. 25	Oct. 1	Oct. 10	Oct. 15	6	15	20	
Average.....						2.884	9.069	11.862	41
Maximum.....						7	18	23	
Minimum.....						1	5	7	

SECOND BROOD OF LARVÆ.

Time of hatching.—By reference to Table XX it will be noted that second-brood codling-moth eggs were hatching from August 23 to October 15. Hence the larvæ were hatching over a period of nearly two months.

Length of feeding period.—Observations on the feeding period of the second-brood larvæ are given in Table XXI. Although hatching continued until October 15, none of the larvæ which entered the fruit later than September 11 matured. The first of the second-brood larvæ left the fruit September 25, the last November 21. The average feeding period for all larvæ was 49.160 days; maximum, 77 days; minimum, 31 days. The average feeding period for 47 male larvæ was 46.659 days; maximum, 77 days; minimum, 31 days. The average feeding period for 57 female larvæ was 50.245 days; maximum, 72 days; minimum, 33 days. It will again be noted that the feeding period of female larvæ is longer than that of the male.

TABLE XXI.—*Length of feeding period of second-brood larvæ, stock-jar method, Winthrop, Me., 1913.*

[Figures in parentheses () denote sex undetermined.]

		Length of feeding period in specified days.																	
Number of individuals.	Date of entering fruit.	31		33		34		36		37		38		39		40		41	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
3	Aug. 23															1			1
3	Aug. 24					1						1			1		1		
9	Aug. 25	1								1				1					1
7	Aug. 26			1	1							1			1		1	1	
8	Aug. 27							2				1	1	1	1		1		
10	Aug. 28							1		1		3	1	1	1				
3	Aug. 29																1		
1	Aug. 30																		
20	Sept. 1																		
13	Sept. 2													1	2	1			
2	Sept. 3																		
11	Sept. 4																		
2	Sept. 5																		
5	Sept. 6																		
5	Sept. 8																		
2	Sept. 9																		
2	Sept. 11																		
106 ♂ and ♀.		1	0	1	1	1	0	3	0	2	0	4	4	3	4	2	4	1	2
Sex undetermined.																			
Total.....		1		2		1		3		2		8		7		6		3	

TABLE XXI.—Length of feeding period of second-brood larvæ, stock-jar method, Winthrop, Me., 1913—Continued.

		Length of feeding period in specified days.																	
Number of individuals.	Date of entering fruit.	42		43		44		45		46		47		48		49		50	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
3	Aug. 23					1													
3	Aug. 24																		
9	Aug. 25			1	1			1								1			
7	Aug. 26									1									
8	Aug. 27																	1	
10	Aug. 28			1		1													
3	Aug. 29				1						1								
1	Aug. 30																1		
20	Sept. 1	1				3		2		1			1	2				2	
13	Sept. 2			1		1		1		1		1							
2	Sept. 3													1					
11	Sept. 4							1				1							
2	Sept. 5																		
5	Sept. 6																		
5	Sept. 8																		
2	Sept. 9																	1	
2	Sept. 11																		
106 ♂ and ♀.		1	0	3	2	5	1	2	3	0	3	2	1	1	3	1	1	0	4
Sex undetermined.																			
Total.....		1		5		6		5		3		3		4		2		4	

		Length of feeding period in specified days.																	
Number of individuals.	Date of entering fruit.	51		52		53		54		55		56		58		61		62	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
3	Aug. 23																		
3	Aug. 24																		
9	Aug. 25																		
7	Aug. 26																		
8	Aug. 27															1			
10	Aug. 28																		
3	Aug. 29																		
1	Aug. 30																		
20	Sept. 1							2	2			2	1		1				
13	Sept. 2						3				1								
2	Sept. 3				1														
11	Sept. 4		2			2	1												
2	Sept. 5																		
5	Sept. 6				1														
5	Sept. 8		1															1	
2	Sept. 9																		
2	Sept. 11															1			
106 ♂ and ♀.		0	3	1	1	2	4	2	2	0	1	2	1	0	1	2	0	0	1
Sex undetermined.																			
Total.....		3		2		6		4		1		3		1		2		1	

TABLE XXI.—Length of feeding period of second-brood larvæ, stock-jar method, Winthrop, Me., 1913—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		64		65		66		69		70		71		72		75		77	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
3	Aug. 23																		
3	Aug. 24																	1	
9	Aug. 25																		
7	Aug. 26															1			
8	Aug. 27																		
10	Aug. 28																		
3	Aug. 29																		
1	Aug. 30																		
20	Sept. 1																		
13	Sept. 2																		
2	Sept. 3																		
11	Sept. 4		1				1											(2)	
2	Sept. 5			1	1														
5	Sept. 6	1	1											1					
5	Sept. 8								1	3									
2	Sept. 9												1						
2	Sept. 11																		
106 ♂ and ♀		1	2	1	1	0	1	0	1	1	3	0	1	0	1	1	0	1	0
Sex undetermined.																		2	
Total.....		3		2		1		1		4		1		1		1		3	

Average length of feeding period, 106 male and female larvæ, 49.160 days; 47 male larvæ, 46.659 days; 57 female larvæ, 50.245 days.

Maximum length of feeding period, 106 male and female larvæ, 77 days; 47 male larvæ, 77 days; 57 female larvæ, 72 days.

Minimum length of feeding period, 106 male and female larvæ, 31 days; 47 male larvæ, 31 days; 57 female larvæ, 33 days.

BAND RECORD EXPERIMENT, 1913-14.

As previously stated, the collecting of codling-moth larvæ from banded trees serves as a basis for comparison of the larvæ living under natural conditions with those reared under laboratory conditions. As shown in Table XXII, the first larvæ left the fruit of the banded trees July 21, while the last were collected October 13. The first of the larvæ reared at the insectary left the fruit July 25.

Out of a total of 1,012 larvæ collected from the bands, but 8 larvæ (less than 1 per cent) transformed during 1913. One parasite (*Ascogaster carpocapsæ* Vier.) emerged in 1913.

Owing to the exceptionally severe winter of 1913-14 the mortality of the wintering larvæ was very high. It was computed that 81.52 per cent of the larvæ were killed, due to the low temperatures.

In the spring of 1914, 82 moths and 96 parasites emerged. The parasites were all of the species *Ascogaster carpocapsæ* Vier.

The well known codling-moth enemy *Tenebroides corticalis* Melsh. was frequently found attacking the larvæ beneath the bands.

TABLE XXII.—*Band record experiment, Winthrop, Me., 1913-14.*

No. of record.	Date of collecting.	Number of larvæ.	Number of moths, 1913.	Number of parasites, 1913.	Number of moths, 1914.	Number of parasites, 1914.	Total number dead larvæ.
1	July 21	2	2				0
2	July 24	3	3				0
3	July 27	4	2	1			1
4	July 30	5	1				4
5	Aug. 2	11			1		10
6	Aug. 5	5				1	4
7	Aug. 8	4			2	2	0
8	Aug. 11	15			2	2	11
9	Aug. 14	25			2	4	19
10	Aug. 17	46			3	5	38
11	Aug. 20	92			8	10	74
12	Aug. 23	102			6	13	83
13	Aug. 26	70			1	14	55
14	Aug. 29	78			5	8	65
15	Sept. 1	94			3	8	85
16	Sept. 4	123			5	11	107
17	Sept. 7	77			6	7	64
18	Sept. 10	51			7	5	39
19	Sept. 13	38			10	1	27
20	Sept. 16	26			5	4	17
21	Sept. 19	27			4	1	22
22	Sept. 22	13			2	0	11
23	Sept. 25	30			2		28
24	Sept. 28	13			3		10
25	Oct. 1	22			2		20
26	Oct. 4	10			1		9
27	Oct. 7	11			1		10
28	Oct. 10	9			1		8
29	Oct. 13	6			0		6
Total.....		1,012	8	1	82	96	825

Parasites, *Ascogaster carpocapsæ* Vier.

SEASONAL-HISTORY STUDIES OF 1914.

The life-history studies of the codling moth which were commenced in 1913 were continued during the season of 1914. Although the notes secured in 1913 were complete in themselves, it was considered desirable to extend the observations over a period of at least two seasons, in order to note any differences in the behavior of the insect due to climatic variations. All of the explanations and descriptions of the methods used in the studies of 1913 are applicable to the investigations of 1914.

SOURCE OF REARING MATERIAL.

The overwintering larvæ consisted of the larvæ which were reared under laboratory conditions and the larvæ collected from the banded trees, as well as miscellaneous larvæ which were secured from wormy apples. The miscellaneous larvæ passed the winter in corrugated paper strips, while the remainder of the larvæ wintered in the "cocoon racks." The larvæ were kept under normal outdoor conditions throughout the winter.

WINTER-KILLED LARVÆ.

Owing to the low temperatures during the winter of 1913-14 a high mortality of the codling-moth larvæ occurred. The number of larvæ from the banded trees killed by the winter temperatures is estimated at 81.52 per cent. The number of winter-killed larvæ which had been reared under laboratory conditions was 86.61 per cent. The United States Weather Bureau, Climatological Report for the New England section, January, 1914, makes special mention of the cold wave on January 13 and 14. This report states that "at

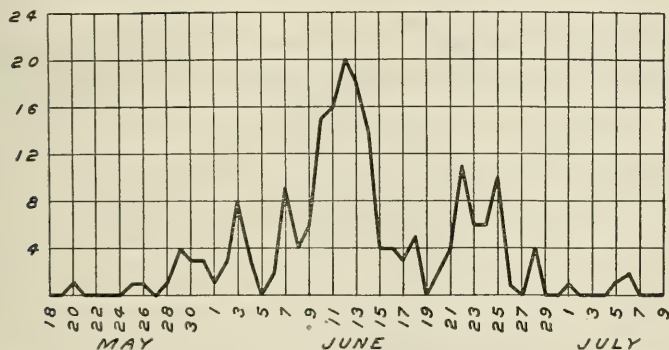


FIG. 5.—Diagram showing pupation of the spring brood of the codling moth in 1914 at Winthrop, Me.
(Original.)

many stations of long record all previous minimum temperatures were exceeded on these dates."

SPRING BROOD OF PUPÆ.

Time of pupation.—The first of the spring-brood larvæ pupated May 20, the last July 6. (See fig. 5.) Maximum pupation occurred on June 12, when 20 larvæ pupated. In the preceding year the maximum pupation took place on June 6. (See Table XXIII for the time of pupation.)

TABLE XXIII. — *Time of pupation of overwintering larvæ, Winthrop, Me., 1914.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
May 20	1	June 3	8	June 13	18	June 23	6
May 25	1	June 4	3	June 14	14	June 24	6
May 26	1	June 6	2	June 15	4	June 25	10
May 28	1	June 7	9	June 16	4	June 26	1
May 29	4	June 8	4	June 17	3	June 28	4
May 30	3	June 9	6	June 18	5	July 1	1
May 31	3	June 10	15	June 20	2	July 5	1
June 1	1	June 11	16	June 21	4	July 6	2
June 2	3	June 12	20	June 22	11	Total..	197

Length of the pupal stage.—In Table XXIV the length of the pupal stage of 196 spring-brood pupæ is given. The average length of the pupal stage was 22.581 days; maximum, 44 days; minimum, 11 days.

TABLE XXIV.—*Length of pupal stage of spring-brood pupæ, Winthrop, Me., 1914.*

Number of individuals.	Date of pupation.	Length of pupal stage in specified days.																							
		11	12	14	15	16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	35	43	44
1	May 25	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1	May 26	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1	May 28	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	May 29	...	...	...	...	...	...	...	...	...	1	1	1	2	...	...	...	...	...	...	...	...	...	...	...
3	May 30	...	...	...	...	...	...	...	...	...	1	1	1	...	1	...	...	...	...	...	...	...	...	...	...
3	May 31	...	...	...	...	...	...	...	...	...	1	2	...	...	...	1	...	...	...	...	...	...	...	...	...
1	June 1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
3	June 2	...	...	...	...	...	...	...	...	...	1	1	1	1	...	...	...	...	...	...	...	...	...	...	...
8	June 3	...	...	1	...	...	...	...	1	3	1	2	...	...	...	...	...	...	...	...	...	...	...	...	...
3	June 4	...	...	...	...	...	...	...	...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	1	...
2	June 6	...	...	...	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	June 7	...	...	...	...	...	...	1	2	3	...	2	...	...	...	...	...	...	1	...	...	...	...	...	...
4	June 8	...	...	...	...	...	...	3	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	June 9	...	...	...	...	...	...	...	1	...	...	...	2	...	...	1	1	1	...	...	...	...	...	...	...
15	June 10	...	...	...	...	...	...	...	2	...	8	...	2	1	...	1	...	...	...	...	...	...	...	1	...
16	June 11	...	...	...	...	...	...	...	2	...	4	5	2	1	...	...	...	...	...	1	...	...	...	...	...
20	June 12	...	1	1	...	...	...	...	1	...	3	8	3	1	...	...	...	...	1	...	...	1	...	...	...
18	June 13	...	...	...	...	...	...	...	1	...	2	9	2	...	2	1	...	...	1	...	...	...	...	...	...
14	June 14	...	...	...	1	...	...	...	...	...	5	3	2	...	...	...	...	...	1	1	...	...	1	...	...
4	June 15	...	...	...	...	...	...	...	...	...	1	2	1	...	...	...	...	...	...	...	...	...	...	...	...
4	June 16	...	...	...	...	...	...	...	...	2	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...
3	June 17	...	...	...	...	...	...	...	...	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	June 18	...	...	...	...	...	1	...	1	...	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...
2	June 20	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
4	June 21	...	...	...	...	...	...	...	1	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	June 22	...	1	1	...	...	...	...	5	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	June 23	...	...	...	...	...	1	2	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	June 24	...	...	...	...	...	1	2	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	June 25	...	...	...	1	1	2	3	2	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1	June 26	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	June 28	...	1	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1	July 1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1	July 5	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	July 6	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
196 pupæ.....		1	2	3	4	7	1	9	21	24	13	35	40	14	3	6	2	1	4	1	1	1	1	1	1

Average length of the pupal stage, 22.581 days.

Maximum length of the pupal stage, 44 days.

Minimum length of the pupal stage, 11 days.

SPRING BROOD OF MOTHS.

Time of emergence of moths.—In Table XXV is shown the emergence record of 210 spring-brood moths. On June 14 moth emergence commenced and continued until July 19. The maximum emergence occurred July 7, on which date 28 moths appeared. In 1913 the time of moth emergence extended from June 18 to July 20. In 1914 the date of full bloom (Baldwin) was the same as in 1913, namely, May 28.

TABLE XXV.—*Time of emergence of moths of spring brood, Winthrop, Me., 1914. (See fig. 6.)*

Date.	Total.	Date.	Total.	Date.	Total.
June 14	1	July 1	2	July 13	12
June 18	2	July 3	12	July 14	9
June 21	3	July 4	10	July 15	8
June 22	3	July 5	13	July 16	3
June 23	2	July 6	17	July 17	6
June 24	7	July 7	28	July 18	1
June 25	3	July 8	15	July 19	2
June 26	7	July 9	5		
June 27	6	July 10	3		210
June 28	6	July 11	7		
June 30	5	July 12	12		

Time of egg deposition.—The time of egg deposition by moths of the spring brood extended from June 24 to August 5. The average

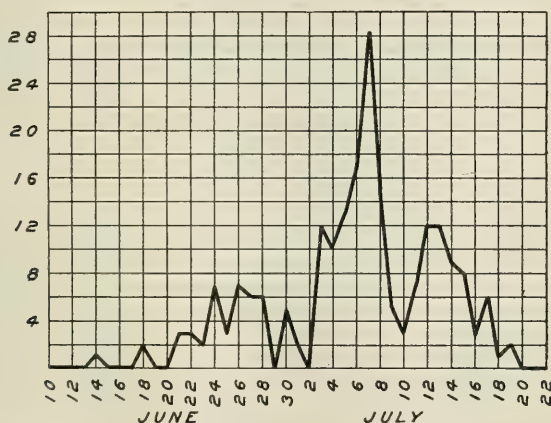


FIG. 6.—Diagram showing emergence of the spring brood of moths of the codling moth in 1914 at Winthrop, Me. (Original.)

number of days from the time of the emergence of moth to first oviposition was 3.272 days; maximum, 7 days; minimum, 2 days. The average number of days of oviposition was 13.636; maximum, 23 days; minimum, 7 days. The average number of days from the time of the emergence of the moth to the end of oviposition was 16 days; maximum, 24 days; minimum, 9 days. (See Table XXVI.)

TABLE XXVI.—*Oviposition by moths of spring brood in rearing cages, Winthrop, Me., 1914.*

Cage.	Number of moths.	Sex.		Date of—			Number of days—		
		♀	♂	Emergence.	First oviposition.	Last oviposition.	Before oviposition.	Duration of oviposition.	From emergence to end of oviposition.
11	{ 1 2 }	2	1	{ June 14 June 18 }	{ June 25 June 24 }	{ June 26 July 1 }	-----	-----	-----
2	{ 3 3 }	1	2	{ June 21 June 22 }	{ June 24 June 24 }	{ July 1 July 1 }	3	8	11
13	{ 2 6 3 }	4	10	{ June 23 June 24 June 25 }	{ July 1 July 1 July 1 }	{ July 11 July 11 July 11 }	-----	-----	-----
14	{ 6 6 5 }	6	13	{ June 26 June 27 June 28 }	{ July 4 July 4 July 4 }	{ July 18 July 18 July 18 }	-----	-----	-----
15	{ 5 2 }	2	5	{ June 30 July 1 }	{ July 5 July 5 }	{ July 16 July 16 }	-----	-----	-----
6	12	6	6	July 3	July 8	July 14	5	7	11
7	10	3	7	July 4	July 11	July 20	7	10	16
8	13	7	6	July 5	July 8	do	3	13	15
9	17	6	11	July 6	do	July 30	2	23	24
10	28	13	15	July 7	July 9	do	2	22	23
11	14	7	7	July 8	July 11	July 25	3	15	17
12	{ 5 3 }	2	6	{ July 9 July 10 }	{ July 14 July 14 }	{ July 16 July 16 }	-----	-----	-----
13	7	4	3	July 11	do	July 20	3	7	9
14	12	5	7	July 12	July 15	July 25	3	11	13
15	9	4	5	July 14	July 17	Aug. 3	3	18	20
16	{ 8 3 6 1 2 }	9	11	{ July 15 July 16 July 17 July 18 July 19 }	{ July 18 July 18 July 18 July 18 July 19 }	{ Aug. 5 Aug. 5 Aug. 5 Aug. 5 Aug. 5 }	-----	-----	-----
17	12	7	5	July 13	July 15	July 30	2	16	17
Number of male moths.....				88	Average.....		3.272	13.636	16
Number of female moths.....				120	Maximum.....		7	23	24
Total number of moths.....				208	Minimum.....		2	7	9
Total number of eggs.....				2,907					

¹ Not used in the averages.

Number of eggs per female.—As recorded in Table XXVI, 120 female moths confined in cages with male moths deposited a total of 2,907 eggs. From these data the average number of eggs per female was found to be 24.225.

Length of life of moths.—In Table XXVII will be found the length of the life of 72 male and 66 female moths of the spring brood. The average life of the male moth was 13.708 days; of the female, 13.621 days. The maximum life of the male moth was 32 days; of the female, 28 days. The minimum life of the male moth was 2 days; of the female, 1 day.

TABLE XXVII.—*Length of life of male and female moths of spring brood in captivity. Summary of records of 138 individual moths, Winthrop, Me., 1914.*

Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
<i>Days.</i>		<i>Days.</i>		<i>Days.</i>		<i>Days.</i>	
2	1	1	2	17	6	17	4
3	1	5	1	18	3	18	4
6	3	6	6	19	5	20	2
7	3	7	2	20	3	21	2
8	1	8	3	21	1	22	2
9	9	9	2	22	1	24	1
10	7	10	4	23	1	25	1
11	3	11	2	24	1	27	1
12	5	12	3	27	1	28	2
13	5	13	10	32	1		
14	4	14	7				
15	2	15	4		72		66
16	5	16	1				

Average length of life of male moths, 13.708 days; female moths, 13.621 days.

Maximum length of life of male moths, 32 days; female moths, 28 days.

Minimum length of life of male moths, 2 days; female moths, 1 day.

THE FIRST GENERATION.

FIRST BROOD OF EGGS.

Length of incubation.—Observations of the embryological changes and incubation periods of 2,672 eggs are recorded in Table XXVIII. Of this number, 2,633 (98.54 per cent) hatched. The average number of days from the time of oviposition to the appearance of the red ring was 2.599; maximum, 5 days; minimum, 2 days. The average number of days from the time of oviposition to the appearance of the black spot was 6.139; maximum, 10 days; minimum, 5 days. The average incubation period was 7.797 days; maximum, 13 days; minimum, 6 days.

TABLE XXVIII.—Length of incubation of first-brood eggs, Winthrop, Me., 1914.

No. of observation.	Number of eggs.	Date—				Appearance of—		Incubation period.	Number dead.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.		
						<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	
1	4	June 24	June 27	July 4	July 6	3	10	12	1
2	3	June 25	June 28	do	July 7	3	9	12	
3	15	do	do	do	July 8			13	1
4	4	June 26	June 30	July 5	do	4	9	12	
5	2	June 27	July 2	July 7	do	5	10	11	
6	43	July 1	July 4	July 8	July 10	3	7	9	
7	7	do	do	do	July 11			10	
8	18	July 3	July 5	July 9	July 10	2	6	7	
9	2	do	do	do	July 11			8	
10	6	July 4	July 6	July 11	July 12	2	7	8	
11	2	do	do	do	July 13			9	
12	92	July 5	July 7	July 12	do	2	7	8	
13	22	do	do	do	July 14			9	7
14	29	July 6	July 8	July 13	do	2	7	8	
15	12	do	do	do	July 15			9	
16	132	July 8	July 11	July 14	do	3	6	7	
17	84	do	do	do	July 16			8	5
18	19	July 9	July 12	July 15	do	3	6	7	
19	9	do	do	do	July 17			8	
20	115	July 10	July 13	July 16	do	3	6	7	
21	27	do	do	do	July 18			8	4
22	102	July 11	July 13	July 16	July 17	2	5	6	
23	20	do	do	do	July 18			7	
24	110	July 12	July 14	July 17	do	2	5	6	
25	160	do	do	do	July 19			7	
26	21	do	do	do	July 20			8	
27	101	July 13	July 15	July 18	do	2	5	7	
28	17	do	do	do	July 21			8	2
29	106	July 14	July 16	July 20	do	2	6	7	
30	12	do	do	do	July 22			8	
31	70	July 15	July 17	July 21	do	2	6	7	
32	60	do	do	do	July 23			8	
33	142	July 16	July 18	July 22	do	2	6	7	
34	27	do	do	do	July 24			8	7
35	187	July 17	July 20	July 23	do	3	6	7	
36	52	do	do	do	July 25			8	8
37	42	July 18	July 21	July 24	July 26	3	6	8	
38	90	do	do	do	July 27			9	3
39	17	July 19	July 22	July 25	do	3	6	8	
40	12	do	do	do	July 28			9	
41	63	July 20	July 23	July 26	do	3	6	8	
42	28	do	do	do	July 29			9	
43	33	July 21	July 24	July 28	July 30	3	7	9	
44	9	do	do	do	July 31			10	
45	38	July 22	July 25	July 29	do	3	7	9	
46	17	do	do	do	Aug. 1			10	
47	16	July 23	July 26	July 30	do	3	7	9	
48	6	do	do	do	Aug. 2			10	
49	57	July 24	July 27	July 31	do	3	7	8	
50	9	do	do	do	Aug. 3			9	
51	106	July 25	July 28	Aug. 1	do	3	7	9	
52	70	do	do	do	Aug. 4			10	
53	13	July 26	July 29	Aug. 3	do	3	8	9	
54	16	do	do	do	Aug. 5			10	
55	1	July 27	July 30	Aug. 3	do	3	7	9	
56	15	do	do	do	Aug. 6			10	
57	7	July 28	July 31	Aug. 4	do	3	7	9	
58	16	do	do	do	Aug. 7			10	
59	12	July 30	Aug. 3	Aug. 6	do	4	7	8	
60	89	do	do	do	Aug. 8			9	1
61	23	July 31	Aug. 4	Aug. 7	Aug. 9	4	7	9	
62	9	Aug. 1	do	Aug. 8	do	3	7	8	
63	18	Aug. 2	Aug. 5	Aug. 9	Aug. 10	3	7	8	
64	5	Aug. 3	Aug. 6	do	Aug. 11	3	6	8	
65	1	Aug. 5	Aug. 8	Aug. 11	Aug. 12	3	6	7	
Average.....						2.599	6.139	7.797	39
Maximum.....						5	10	13	
Minimum.....						2	5	6	

FIRST BROOD OF LARVÆ.

Time of hatching.—The first-brood larvæ commenced to hatch July 6. The last of the larvæ hatched August 12. Hatching, therefore, extended for a period of slightly over one month. The maximum number of larvæ hatched July 24. (See Table XXVIII.)

Length of the feeding period of the transforming larvæ.—During the season of 1914 two methods, namely, the stock-jar and bagged-fruit methods, were used for determining the feeding period of the first-brood larvæ. These methods are described on page 10.

As in 1913, only a very small number of the first-brood larvæ transformed to first-brood moths. Out of a total of 845 larvæ reared at the laboratory 12 (1.4 per cent) transformed.

In Table XXIX is given the length of the feeding period of the transforming larvæ of the first brood (stock-jar method). The average length of the feeding period for male and female larvæ was 19.666 days; maximum, 21 days; minimum, 17 days. Average for male larvæ, 21 days; maximum, 21 days; minimum, 21 days. Average for female larvæ, 19.285 days; maximum, 21 days; minimum, 17 days.

TABLE XXIX.—*Length of feeding period of transforming larvæ of the first brood, stock-jar method, Winthrop, Me., 1914.*

No. of observation.	Date of—		Sex.	Days of feeding.
	Hatching.	Leaving fruit.		
1	July 6	July 24	♂	18
2	...do...	July 27	♂	21
3	July 8	...do....	♀	19
4	...do...	July 28	♀	20
5	...do...	July 29	♀	21
6	July 9	...do....	♀	20
7	July 10	July 27	♀	17
8	...do...	July 31	♀	21
9	July 13	Aug. 2	♀	20

Average length of feeding period, male and female larvæ, 19.666 days; male, 21 days; female, 19.285 days.

Maximum length of feeding period, male and female larvæ, 21 days; male, 21 days; female, 21 days.

Minimum length of feeding period, male and female larvæ, 17 days; male, 21 days; female, 17 days.

The length of the feeding period of the transforming larvæ of the first brood (bagged-fruit method) is given in Table XXX. The average length of the feeding period was 25.333 days; maximum, 26 days; minimum, 24 days. The average for the male larvæ was 25 days; maximum, 26 days; minimum, 24 days. No record for female larvæ was secured.

The average feeding period for all transforming larvæ was 21.082 days, as given in Table XXXVIII.

TABLE XXX.—*Length of the feeding period of transforming larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1914.*

No. of observation.	Date of—		Sex.	Days of feeding.
	Hatching.	Leaving fruit.		
1	July 15	Aug. 10	.....	26
2	July 17	...do....	♂	24
3	July 19	Aug. 14	♂	26

Average length of feeding period, male and female larvæ, 25.333 days; male, 25 days.

Maximum length of feeding period, male and female larvæ, 26 days; male, 26 days.

Minimum length of feeding period, male and female larvæ, 24 days; male, 24 days.

Length of the feeding period of wintering first-brood larvæ (stock-jar method).—Observations were taken on the length of feeding of 341 larvæ, as is given in Table XXXI. The average length of the feeding period for all larvæ was 25.717 days; maximum, 46 days; minimum, 19 days. The average length of feeding for the male larvæ was 23.935 days; for the female larvæ, 27.022 days. The maximum length of the feeding period for the male larvæ was 46 days; for the female larvæ, 46 days. The minimum length of the feeding period for the male larvæ was 19 days; for the female larvæ, 19 days.

TABLE XXXI.—*Length of feeding period of the wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1914.*

[Figures in parentheses () denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		19		20		21		22		23		24		25		26	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
2.....	July 7				1							1					
4.....	July 8				1					1		1					1
2.....	July 9														1		
5.....	July 11		1				1			1		1					
4.....	July 12	1	1		1		1										
3.....	July 13			1			1					(1)					
9.....	July 14			1			1							1	1	(1)	
14.....	July 15									1		2	3				
9.....	July 16															1	1
18.....	July 17							1						2	2	1	1
11.....	July 18									1	1	1	2				
19.....	July 19									1	1		2	1	(1)		
3.....	July 20									1		1					
20.....	July 21									1		(1)2	1		4		
6.....	July 22							1		1					1	1	1
6.....	July 23										2	1	3				
11.....	July 24		1					1		1		1	2				2
33.....	July 25							1	1	1	4	2	4	1	(1)	1(1)	3
4.....	July 26													1	1		
9.....	July 28							(1)			1		2		2		
10.....	July 29											1	3		2		2
19.....	July 31					1		3	1	1	4	1	3	1			
24.....	Aug. 1			1	(1)	3		2	1	2	4	4	3		1		1
16.....	Aug. 2					1					3	2	1	2	3	1	1
40.....	Aug. 3			1	1	4	1	3(1)	1	3	1	5	2	(2)	1		1
13.....	Aug. 4						1	(1)	1	1	(1)						2
10.....	Aug. 5					3				1			1	2			
5.....	Aug. 6								1						2	1	
10.....	Aug. 8											1	1	3	1	2	
2.....	Aug. 9																
341 ♂ and ♀.....		1	3	4	3	13	6	14	6	18	21	28	36	17	22	8	16
Sex undetermined.....		0		1		0		3		1		2		4		2	
Total.....		4		8		19		23		40		66		43		26	

TABLE XXXI.—Length of feeding period of the wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1914—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		27		28		29		30		31		32		33		34	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
2.....	July 7																
4.....	July 8																
2.....	July 9										1						
5.....	July 11					(1)											
4.....	July 12																
3.....	July 13																
9.....	July 14		1		1					1	1						
14.....	July 15	2		1		1				(1)2	2						
9.....	July 16																
18.....	July 17	1		1	1	2		1									
11.....	July 18		2	2	1		1										
19.....	July 19	(1)	3		1		1		2			1	1				
3.....	July 20	1															
20.....	July 21		2	2	2	(1)		1				1				1	
6.....	July 22			1													
6.....	July 23																
11.....	July 24				1		1										
33.....	July 25	(2)		(1)1	3	1	1		1				1	1			
4.....	July 26			2													
9.....	July 28		2						1								
10.....	July 29													(1)		1	
19.....	July 31	1													1		1
24.....	Aug. 1								1								
16.....	Aug. 2							(1)	1								
40.....	Aug. 3	1	1	1	2	1(1)	4						1		1		
13.....	Aug. 4			1(1)	2												
10.....	Aug. 5						1										
5.....	Aug. 6																
10.....	Aug. 8				2												
2.....	Aug. 9	1					1										
341 ♂ and ♀.....		7	11	12	16	5	10	2	6	5	4	1	4	1	2	1	2
Sex undetermined.....		3		2		3		1		1		0		1		0	
Total.....		21		30		18		9		10		5		4		3	

TABLE XXXI.—*Length of feeding period of the wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1914—Continued.*

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.													
		35		36		37		38		40		41		46	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
2.....	July 7														
4.....	July 8														
2.....	July 9														
5.....	July 11														
4.....	July 12														
3.....	July 13														
9.....	July 14														
14.....	July 15				1	1			1						
9.....	July 16	(1)								1					
18.....	July 17														
11.....	July 18														
19.....	July 19														
3.....	July 20											1		1	1
20.....	July 21						1								
6.....	July 22														
6.....	July 23														
11.....	July 24		1												
33.....	July 25				1										
4.....	July 26														
9.....	July 28														
10.....	July 29														
19.....	July 31		1												
24.....	Aug. 1														
16.....	Aug. 2														
40.....	Aug. 3														
13.....	Aug. 4														
10.....	Aug. 5														
5.....	Aug. 6														
10.....	Aug. 8														
2.....	Aug. 9														
341 ♂ and ♀.....		0	2	0	2	1	1	0	1	0	1	1	0	1	1
Sex undetermined.....		1		0		0		0		0		0		0	
Total.....		3		2		2		1		1		1		2	

Average length of feeding period, 341 male and female larvæ, 25.717 days; 140 male larvæ, 23.935 days; 176 female larvæ, 27.022 days.

Maximum length of feeding period, 341 male and female larvæ, 46 days; 140 male larvæ, 46 days; 176 female larvæ, 46 days.

Minimum length of feeding period, 341 male and female larvæ, 19 days; 140 male larvæ, 19 days; 176 female larvæ, 19 days.

Length of the feeding period of wintering first-brood larvæ (bagged-fruit method).—Table XXXII records the feeding period of 492 wintering first-brood larvæ. The average feeding period of these larvæ was 31.865 days; maximum, 55 days; minimum, 24 days. The average feeding period for 226 male larvæ was 30.960 days; maximum, 55 days; minimum, 24 days. The average feeding period for 213 female larvæ was 32.436 days; maximum, 55 days; minimum, 25 days.

TABLE XXXII.—*Length of feeding period of the wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1914.*

[Figures in parentheses () denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		24		25		26		27		28		29		30		31	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
20.	July 10			(1)	1			2	1(1)	3	1	1(1)	2				
8.	July 11			(1)		2								1		2	1
22.	July 13			1	1	1		4	4	(1)3	3		1	1			
29.	July 14			3	1(2)	1	2	4	2	4	2(3)	1		1	1		1
22.	July 15					1				1		1	(1)	2	3		
20.	July 16										1	3		(1)2	1	1	2
42.	July 17	1				(1)	1	3		3	3		1	(2)7	4	1	4
42.	July 18			1				2	1	2	3	3	2	4	4	(1)1	2
21.	July 19					1				1			2	1		1	
18.	July 20			2			1	1	1			2	2			1	1
21.	July 21	1				2						2	1	1	3		2
16.	July 22			(1)	1		1	2				2		1		1	1
13.	July 23					2		1	1	1	1			1	2		1
20.	July 24						1	2				2	1	2		1	
42.	July 25							(2)		1	2	4	(1)4	2	1	1	
13.	July 26					1			1			1		1			2
8.	July 27													3			
12.	July 28									1				1			
8.	July 30									1				1			
14.	July 31													1			
3.	Aug. 2													1			
28.	Aug. 3											2	3	2		1	
14.	Aug. 4									1		1				1	
1.	Aug. 5																
4.	Aug. 6									1						1	
5.	Aug. 7									1						1	
15.	Aug. 8																
6.	Aug. 9									1			2				
3.	Aug. 10					1										(1)	
2.	Aug. 11									1	1						
492 ♂ and ♀.		2	0	7	4	12	6	21	11	26	17	30	20	35	20	13	18
Sex undetermined.		0		5		1		3		4		3		3		2	
Total.		2		16		19		35		47		53		58		33	

TABLE XXXII.—Length of feeding period of the wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1914—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		32		33		34		35		36		37		38		39	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
20.....	July 10							1	2								
8.....	July 11						1										
22.....	July 13	(2)															
29.....	July 14			1													
22.....	July 15	3	2	1	(1)2			4									
20.....	July 16		1	2	(1)2		2	1									
42.....	July 17		2	1	1	2	1	1					2				
42.....	July 18	(1)2	1	3	(1)4		1										
21.....	July 19	2	2	1	1		2			1						(1)	
18.....	July 20	1	(3)			(2)	1										
21.....	July 21	3	2	3								1					
16.....	July 22		2			1	1	1	1		1						
13.....	July 23		1	1								1					
20.....	July 24	1	1				1	1	2			1		1	(1)	1	
42.....	July 25	2	3	1	2			1	3	1		2	1	1	2	(1)	2
13.....	July 26	1	1							2							
8.....	July 27		2		(1)	2											
12.....	July 28	1(1)	1				1(1)	1				1	2	(1)			
8.....	July 30					2		2						1		1	
14.....	July 31	1	1		3	(1)	1	2		1	1					(1)	
3.....	Aug. 2				1	1											
28.....	Aug. 3				1	1		1	2	1	1	2	1				
14.....	Aug. 4				2		2	2								1	1
1.....	Aug. 5																
4.....	Aug. 6	1	1														1
5.....	Aug. 7			1		1			1								
15.....	Aug. 8	1						1						1	1(1)	3	(1)
6.....	Aug. 9															(1)	1
3.....	Aug. 10							1									
2.....	Aug. 11																
492 ♂ and ♀.....		19	24	14	20	7	14	9	18	7	7	8	8	3	6	2	8
Sex undetermined.....		7		4		3		1		0		0		2		6	
Total.....		50		38		24		28		14		16		11		16	

TABLE XXXII.—*Length of feeding period of the wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1914—Continued.*

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		40		41		42		43		44		45		46		48		55	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
20.....	July 10			1														1	1
8.....	July 11																		
22.....	July 13																		
29.....	July 14																		
22.....	July 15																		
20.....	July 16																		
42.....	July 17											1	1						
42.....	July 18			1						(1)		1							
21.....	July 19																		
18.....	July 20																		
21.....	July 21																		
16.....	July 22																		
13.....	July 23																		
20.....	July 24																1		
42.....	July 25		1			1													
13.....	July 26							1											
8.....	July 27																		
12.....	July 28																		
8.....	July 30																		
14.....	July 31			1															
3.....	Aug. 2																		
28.....	Aug. 3	(1)	4	1		1	1	(1)							1				
14.....	Aug. 4				1	(2)													
1.....	Aug. 5				(1)														
4.....	Aug. 6															1			
5.....	Aug. 7																		
15.....	Aug. 8					1				(2)				(1)					
6.....	Aug. 9		1																
3.....	Aug. 10																		
2.....	Aug. 11																		
492 ♂ and ♀		0	6	4	1	3	1	1	0	0	0	1	1	0	1	1	1	1	1
Sex undetermined....		1		1		2		1		3		0		1		0		0	
Total.....		7		6		6		2		3		2		2		2		2	

Average length of feeding period, 492 male and female larvæ, 31.865 days; 226 male larvæ, 30.960 days; 213 female larvæ, 32.436 days.

Maximum length of feeding period, 492 male and female larvæ, 55 days; 226 male larvæ, 55 days; 213 female larvæ, 55 days.

Minimum length of feeding period, 492 male and female larvæ, 24 days; 226 male larvæ, 24 days; 213 female larvæ, 25 days.

As was noted in 1913, the average feeding period of the transforming larvæ was shorter than that of the overwintering larvæ. Likewise the feeding period of the larvæ reared by the bagged-fruit method was longer than the feeding period of larvæ reared by any other method. The fact that female larvæ feed on an average for a longer time than the male larvæ was again proven in 1914.

Larval life in the cocoon.—The average number of days spent by the larvæ in constructing their cocoons was 6.166; maximum, 9 days; minimum, 3 days. (See Table XXXIII.)

TABLE XXXIII.—*Length of the pupal stage of the first brood, Winthrop, Me., 1914.*

No. of observation.	Date of—			Mak- ing of co- coon.	Pupa- l pe- riod.	No. of ob- serva- tion.	Date of—			Mak- ing of co- coon.	Pupal period.
	Leaving fruit.	Pupa- tion.	Emer- gence.				Leaving fruit.	Pupa- tion.	Emer- gence.		
1	July 24	July 27	Aug. 11	Days. 3	Days. 15	7	July 29	Aug. 5	Aug. 18	Days. 7	Days. 13
2	July 27	Aug. 3	Aug. 17	7	14	8	July 31	Aug. 6	Aug. 20	6	14
3	do.	do.	do.	7	14	9	Aug. 2	Aug. 9	Aug. 27	7	18
4	do.	Aug. 4	Aug. 18	8	14	10	Aug. 10	Aug. 15	Sept. 2	5	18
5	July 28	Aug. 6	Aug. 20	9	14	11	do.	Aug. 18	Sept. 5	8	18
6	July 29	Aug. 2	Aug. 16	4	14	12	Aug. 14	Aug. 17	Sept. 3	3	17
Average.....										6.166	15.250
Maximum.....										9	18
Minimum.....										3	13

FIRST BROOD OF PUPÆ OR SUMMER PUPÆ.

Time of pupation.—Pupation of the first brood commenced July 27 and extended until August 18, as shown in Table XXXIII. (See fig. 7.)

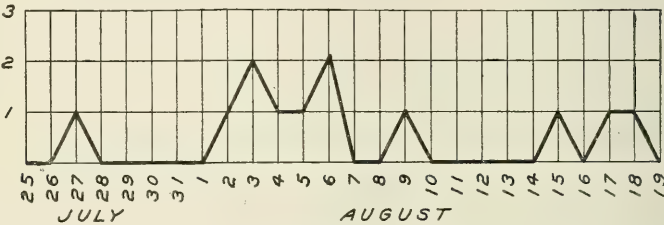


FIG. 7.—Diagram showing pupation of the first brood of the codling moth in 1914 at Winthrop, Me. (Original.)

Length of the pupal stage.—Table XXXIII records the length of the pupal period of 12 individuals. As will be noted, the average length of the pupal period was 15.250 days; maximum, 18 days; minimum, 13 days.

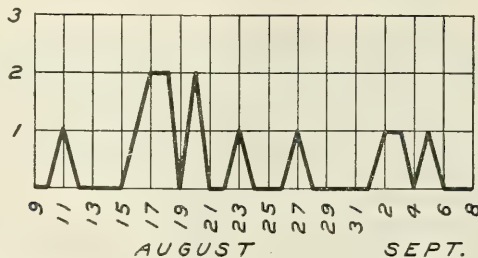


FIG. 8.—Diagram showing emergence of the first brood of moths of the codling moth in 1914 at Winthrop, Me. (Original.)

FIRST OR SUMMER BROOD OF MOTHS.

Time of emergence.—The moths of the summer brood commenced to issue August 11. The last moth emerged September 5. The record of the moth emergence is given in Table XXXIV. (See fig. 8.)

TABLE XXXIV.—*Time of emergence of moths of the first or summer brood, Winthrop, Me., 1914.*

Date of emergence.	Total emergence.	Date of emergence.	Total emergence.
Aug. 11.	1	Aug. 27.	1
Aug. 16.	1	Sept. 2.	1
Aug. 17.	2	Sept. 3.	1
Aug. 18.	2	Sept. 5.	1
Aug. 20.	2		
Aug. 23.	1		13

Time of oviposition.—As shown in Table XXXV, the first eggs were deposited by the summer-brood moths on August 20. The last oviposition occurred September 20.

TABLE XXXV.—*First or summer brood of moths, Winthrop, Me., 1914.*

CAGE I.					CAGE II.				
Date.	Number of moths emerged.	Eggs deposited.	Death of moths.		Date.	Number of moths emerged.	Eggs deposited.	Death of moths.	
			Male.	Female.				Male.	Female.
Aug. 11	1	.....	.....	.....	Sept. 2	1	.....	.....	.....
Aug. 16	1	.....	.....	.....	Sept. 3	1	.....	.....	.....
Aug. 17	2	.....	.....	.....	Sept. 5	1	.....	.....	.....
Aug. 18	2	.....	.....	.....	Sept. 7	.....	Eggs..	.....	.....
Aug. 20	2	Eggs..	.....	.....	Sept. 10	.....	do..	.....	.....
Aug. 22	.....	do..	.....	.....	Sept. 11	.....	do..	.....	.....
Aug. 23	1	.....	.....	.....	Sept. 12	.....	do..	.....	.....
Aug. 24	.....	Eggs..	.....	.....	Sept. 13	.....	do..	.....	.....
Aug. 25	.....	do..	.....	.....	Sept. 14	.....	do..	.....	.....
Aug. 26	.....	.....	.....	1	Sept. 15	.....	do..	.....	.....
Aug. 28	.....	Eggs..	.....	.....	Sept. 18	.....	do..	.....	.....
Aug. 30	.....	.....	2	1	Sept. 20	.....	do..	.....	1
Aug. 31	.....	.....	1	2	Sept. 21	.....	.....	.....	1
Sept. 2	.....	.....	.....	2	Sept. 22	.....	.....	1	.....
	9	.....	3	6		3	.....	1	2

Number of eggs per first-brood female moth.—The total number of eggs deposited by 8 female moths kept in confinement with male moths was 181. Hence the average number of eggs per female was 22.625.

LENGTH OF LIFE CYCLE OF THE FIRST GENERATION.

The life cycle of the first generation of the codling moth is given in two tables, Tables XXXVI and XXXVII. The life cycle considered in these tables extends from the time of egg deposition to the emergence of the moth and hence is not the complete life cycle. For the complete life cycle there should be added to the figures recorded about four days, which is the time from the emergence of the moth until the first oviposition. As will be noted in the tables, the average life cycle (stock-jar method) was 50.222 days; bagged-fruit method averaged for 3 individuals 55 days.

TABLE XXXVI.—*Life cycle of first generation of codling moth as observed by rearing at Winthrop, Me., 1914, stock-jar feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larvæ leaving the fruit.	Pupa-tion.	Emergence of moths.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle. ¹
1 ♀	June 24	July 6	July 24	July 27	Aug. 11	12	18	3	15	48
2 ♀	do.	do.	July 27	Aug. 3	Aug. 17	12	21	7	14	54
3 ♀	June 27	July 8	do.	do.	do.	11	19	7	14	51
4 ♀	do.	do.	July 28	Aug. 6	Aug. 20	11	20	9	14	54
5 ♀	do.	do.	July 29	Aug. 5	Aug. 18	11	21	7	13	52
6 ♀	July 1	July 9	do.	Aug. 2	Aug. 16	8	20	4	14	46
7 ♀	July 3	July 10	July 27	Aug. 4	Aug. 18	7	17	8	14	46
8 ♀	do.	do.	July 31	Aug. 6	Aug. 20	7	21	6	14	48
9 ♀	July 5	July 13	Aug. 2	Aug. 9	Aug. 27	8	20	7	18	53
Average.....						9.666	19.666	6.444	14.444	50.222
Maximum.....						12	21	9	18	54
Minimum.....						7	17	3	13	46

¹ Add 4 days for complete life cycle.TABLE XXXVII.—*Life cycle of first generation of codling moth as observed by rearing at Winthrop, Me., 1914, bagged-fruit feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupa-tion.	Emergence of moths.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle. ¹
1	July 8	July 15	Aug. 10	Aug. 15	Sept. 2	7	26	5	18	56
2 ♂	July 11	July 17	do.	Aug. 18	Sept. 5	6	24	8	18	56
3 ♂	July 12	July 19	Aug. 14	Aug. 17	Sept. 3	7	26	3	17	53
Average.....						6.666	25.333	5.333	17.666	55
Maximum.....						7	26	8	18	56
Minimum.....						6	24	3	17	53

¹ Add 4 days for complete life cycle.

A summary of Tables XXXVI and XXXVII is given in Table XXXVIII, which shows that the average life cycle of the first generation of all individuals was 51.416 days. The complete life cycle would be about 55–56 days.

TABLE XXXVIII.—*Summary of life cycle of first generation of codling moth, Winthrop, Me., 1914.*

	Number of observations.	Larval feeding method.	Days for—				
			Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle. ¹
Average life cycle.....	9	A	9.666	19.666	6.444	14.444	50.222
Do.....	3	B	6.666	25.333	5.333	17.666	55.000
Average of all life cycles.	12	A+B	8.916	21.082	6.166	15.249	51.416

¹ Add 4 days for complete life cycle.

A, stock-jar method; B, bagged-fruit method.

THE SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation.—On August 20 the first egg of the second brood was deposited. Oviposition continued until September 18, reaching the maximum on August 31. Out of 138 eggs deposited 96 (69.56 per cent) hatched. The average incubation period was 10.208 days; maximum, 15 days; minimum, 8 days. The average time from the time of egg deposition to the appearance of the red ring was 4.754 days; maximum, 9 days; minimum, 3 days. The average time for the appearance of the black spot was 8.368 days; maximum, 14 days; minimum, 6 days. (See Table XXXIX.)

TABLE XXXIX.—*Length of incubation period of second-brood eggs, Winthrop, Me., 1914.*

No. of observation.	Number of eggs.	Date—				Appearance of—		Incubation period.	Number dead.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.		
						<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	
1	1	Aug. 20							1
2	8	Aug. 22							8
3	1	Aug. 24	Aug. 29	Sept. 2	Sept. 4	5	9	9	
4	13	Aug. 25	Aug. 30	do.	do.	5	8	10	
5	10	do.			Sept. 5			11	3
6	9	Aug. 26	Aug. 31	Sept. 3	do.	5	8	10	
7	7	do.			Sept. 6			11	3
8	1	Aug. 27	Sept. 1	Sept. 4	Sept. 8	5	8	12	
9	3	Aug. 28	Sept. 4	Sept. 6	Sept. 9	7	9	12	1
10	6	Aug. 31	Sept. 5	do.	Sept. 8	5	6	8	
11	23	do.			Sept. 9			9	4
12	10	Sept. 7	Sept. 12	Sept. 19	Sept. 21	5	12	14	1
13	3	Sept. 10	Sept. 15	Sept. 21		5	11		3
14	2	Sept. 11	do.	do.		4	10		2
15	1	Sept. 12	Sept. 21	Sept. 22	Sept. 23	9	10	11	
16	15	do.			Sept. 24			12	14
17	7	Sept. 13	Sept. 17	Sept. 21	Sept. 23	4	8	10	
18	3	do.			Sept. 24			11	
19	7	Sept. 14	Sept. 17	Sept. 20	Sept. 23	3	6	9	
20	3	Sept. 18	Sept. 22	Oct. 2	Oct. 3	4	14	15	2
Average.....						4.754	8.368	10.208	42
Maximum.....						9	14	15	
Minimum.....						3	6	8	

SECOND BROOD OF LARVÆ.

Time of hatching.—As will be noted in Table XXXIX, the first of the second-brood larvæ hatched September 4. The last of the second-brood larvæ hatched October 3. Hence the period of hatching was about one month.

Length of feeding period.—Observations on the length of the feeding period was limited to 4 individuals. Many of the larvæ which entered the fruit failed to mature. The average feeding period was 42.750 days; maximum, 47 days; minimum, 38 days. The above records are given in Table XL.

TABLE XL.—*Length of feeding period of second-brood larvæ, stock-jar method, Winthrop, Me., 1914.*

Number of larvæ.	Date of hatching.	Date of leaving fruit.	Sex.	Days of feeding.
1	Sept. 8	Oct. 16	♂	38
1	do.....	Oct. 21		43
1	do.....	do.....		43
1	do.....	Oct. 25		47
Average				42.75

BAND-RECORD EXPERIMENT, 1914.

During the season of 1914 a total of 499 larvæ was collected from banded trees. The first larvæ left the fruit August 3, the last October 11. None of these larvæ transformed. (See Table XLI.)

TABLE XLI.—*Band-record experiment, Winthrop, Me., 1914.*

Number of record.	Date of collecting.	Number of larvæ.	Number of moths, 1914.	Number of parasites, 1914.	No. of record.	Date of collecting.	Number of larvæ.	Number of moths, 1914.	Number of parasites, 1914.
1	Aug. 3	1	0	0	14	Sept. 11	20	0	0
2	Aug. 6	3	0	0	15	Sept. 14	31	0	0
3	Aug. 9	0	0	0	16	Sept. 17	43	0	0
4	Aug. 12	7	0	0	17	Sept. 20	42	0	0
5	Aug. 15	1	0	0	18	Sept. 23	54	0	0
6	Aug. 18	2	0	0	19	Sept. 26	16	0	0
7	Aug. 21	15	0	0	20	Sept. 29	0	0	0
8	Aug. 24	8	0	0	21	Oct. 2	6	0	0
9	Aug. 27	17	0	0	22	Oct. 5	11	0	0
10	Aug. 30	23	0	0	23	Oct. 8	2	0	0
11	Sept. 2	30	0	0	24	Oct. 11	5	0	0
12	Sept. 5	82	0	0					
13	Sept. 8	80	0	0					
							499	0	0

COMPARISON OF THE LIFE HISTORY OF THE CODLING MOTH IN 1913 AND 1914.

A comparison of the life history of the codling moth is shown diagrammatically in figure 9. This chart shows the beginning and ending of the different stages of the insect, and, in a general way, the maximum of activity for each phase of the life history. It will be noted that the life histories of the species during 1913 and 1914 corresponded quite closely. Variations were due chiefly to climatic differences which were of comparatively short duration.

In 1913 pupation began somewhat earlier than in 1914. An unusually warm period during the latter part of April and again during the first few days of May, 1913, doubtless exerted some influence on the larvæ. The very early pupæ in 1913, however, were evidently somewhat abnormal and failed to transform to moths. Pupation during both seasons ceased at approximately the same time. The average pupation period of the spring-brood pupæ in 1913 was 19.030 days; in 1914, 22.581 days.

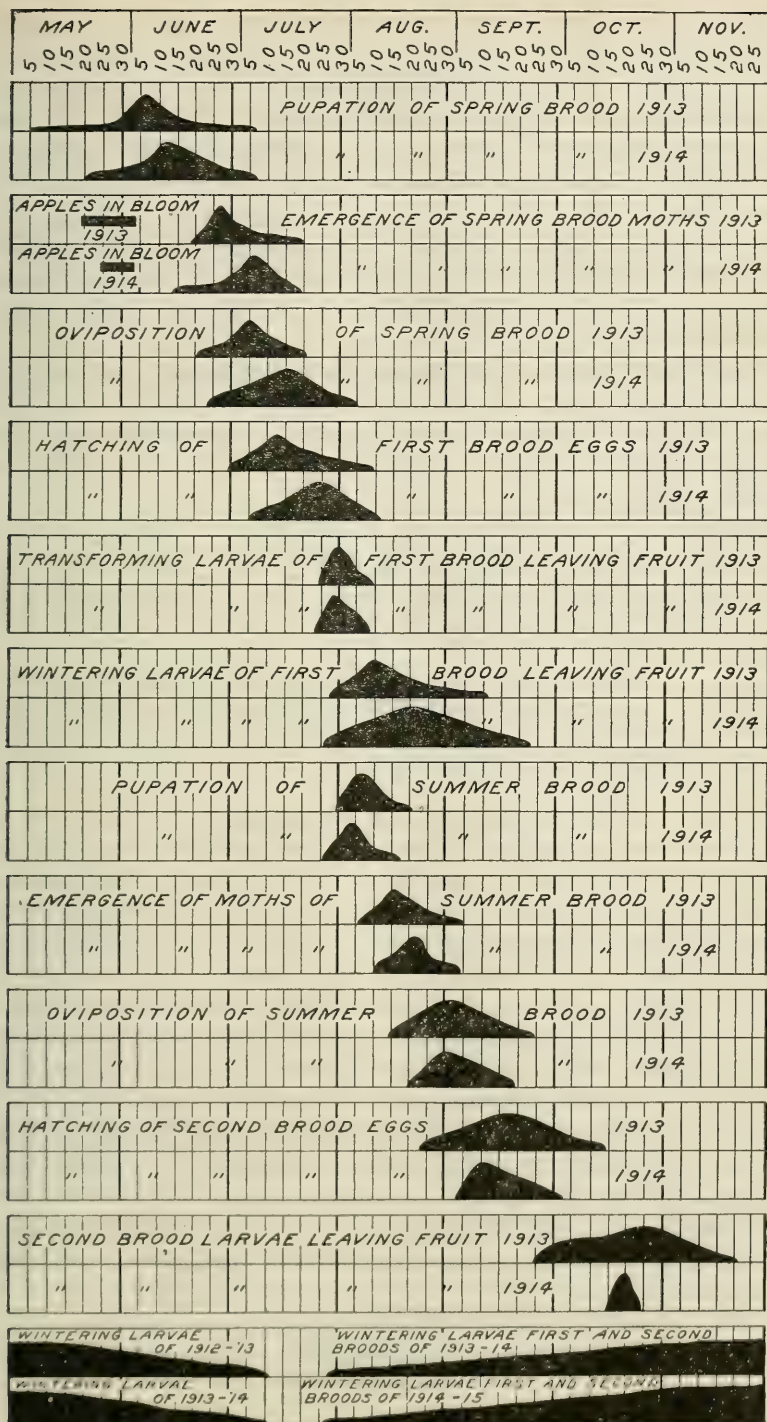


FIG. 9.—Diagram of the seasonal history of the codling moth during the seasons of 1913 and 1914 at Winthrop, Me. (Original.)

In 1913 apples were in bloom from about May 18 to June 4, when the last of the petals had fallen. The temperatures during the blooming period were relatively low, accompanied by considerable precipitation. In 1914 the blooming period was favored with somewhat better weather conditions and, as a result of these climatic conditions, the moths of the spring brood began to issue a few days earlier than in 1913.

The average length of the life of the male spring-brood moth in 1913 was 10.685 days; of the female moth, 12.253 days. In 1914 the average life of the male moth was 13.708 days; female moth, 13.621 days.

Oviposition by moths of the spring brood began at very nearly the same time each year. In 1914, however, the period of oviposition extended about two weeks longer than in the preceding year. The average duration of the oviposition period in 1913 was 14.086 days; in 1914, 13.636 days.

Hatching of the first-brood eggs in 1913 began a few days prior to the date of the earliest hatching in 1914. Likewise hatching ceased in 1913 about three days earlier than in 1914. The average incubation period of the first-brood eggs in 1913 was 8.874 days; in 1914, 7.797 days.

The time of leaving the fruit by transforming larvæ of the first brood was approximately the same during each season. The average feeding period of the transforming larvæ in 1913 was 23.432 days; in 1914, 21.082 days.

The time of leaving the fruit by the overwintering larvæ of the first brood was, during both seasons, a few days later than the time when the earliest transforming larvæ left the fruit. The period of leaving the fruit extended over a longer time in 1914 than in the preceding year. The average feeding period for the overwintering first-brood larvæ in 1913 was 27.884 days; in 1914, 29.348 days.

The pupation period of the first or summer brood covered practically the same time during 1913 and 1914, being slightly earlier in the latter year. The average length of the pupal stage in 1913 was 15.066 days; in 1914, 15.250 days.

The emergence of the first or summer brood of moths extended over approximately the same period during both seasons, being slightly earlier in 1913 than in the following year.

Oviposition by moths of the first or summer brood commenced about five days earlier and ceased about five days later in 1913 than in the following year.

The average life cycle of the first generation in 1913 was 51.566 days; in 1914, 51.416 days. Add four days for complete life cycle.

Hatching of the second-brood larvæ commenced about 12 days earlier in 1913 than in 1914. The average incubation period in 1913 was 11.862 days; in 1914, 10.208 days.

The second brood of larvæ left the fruit over a considerably longer period in 1913 than in the following year. This was due to the smaller number of individuals under observation in 1914 and to the warm weather conditions in November, 1913. The United States Weather Bureau (Climatological Service, North Atlantic States, November, 1913) reports that the "high temperatures caused unusual manifestations in nature." The average feeding period of the second-brood larvæ in 1913 was 49.160 days; in 1914, 42.750 days. The higher average in 1913 was due to the larger number of individuals which were leaving the fruit from September 25 to November 21.

THE CONTROL OF THE CODLING MOTH IN MAINE.

In connection with the life-history studies of the codling moth a series of spraying experiments was conducted in 1913 and 1914. As a result of these investigations it was found that one thorough spray application, as soon as the petals have fallen, is sufficient to control the codling moth. Arsenate of lead, paste 2 pounds or powder 1 pound to each 50 gallons of water, is recommended.

The proper time to spray is illustrated in Plate I. The spraying should be completed before the calyx cup closes too tightly, in order to fill each cup with the poison. This is of vital importance.

SUMMARY AND CONCLUSIONS.

The life-history studies of the codling moth herein recorded were conducted during the seasons of 1913 and 1914 at Winthrop, Me.

The codling moth in Maine has one full generation, a very small percentage (1 to 2 per cent) of the individuals of which transforms to make a partial second generation.

Pupation of the overwintering larvæ begins about the middle of May and extends to the first part of July. The length of the spring-brood pupal stage averaged 21 days.

The moths of the spring brood begin to emerge about two weeks after the petals have fallen and continue to issue for a period of about a month.

The average time from the date of emergence of the moths to first oviposition was about four days.

The oviposition of the spring-brood moths averaged 14 days.

The average length of life of the male spring-brood moth was about 12 days; of the female spring-brood moth about 13 days.

The earliest first-brood eggs were deposited approximately three weeks after the petals dropped.

The incubation period of the first-brood eggs averaged eight days.

The first-brood eggs began to hatch in from four to five weeks after the petals had fallen.

The transforming larvæ of the first brood fed for a period of about 22 days.

The overwintering larvæ of the first brood had an average feeding period of 28 days.

The female larvæ of the first brood fed for a longer period than the male.

The average time spent by the transforming larvæ in constructing their cocoons was about six days.

Approximately from 1 to 2 per cent of the first-brood larvæ transformed to first-brood pupæ. The remainder of the larvæ did not transform until the following spring (spring pupæ).

Pupation of the first or summer brood commenced during the latter part of July. The average length of the first-brood pupal stage was 15 days.

The first or summer brood of moths began to emerge just previous to mid-August and continued to issue for a period of about one month.

Oviposition by moths of the first brood began about mid-August.

The life cycle of the first generation was 51 days. The complete life cycle was about 55 days.

The average incubation period of the second brood of eggs was 11 days.

The average feeding period of the second-brood larvæ was 46 days.

The female larvæ of the second brood fed for a longer time than the male.

The hymenopterous parasite *Ascogaster carpocapsæ* Vier. was frequently reared.

The well-known beetle enemy *Tenebroides corticalis* Melsh. was commonly found attacking codling-moth larvæ.

The codling moth in Maine may be controlled with one spray thoroughly applied as soon as the petals drop. Arsenate of lead, paste 2 pounds or powder 1 pound to each 50 gallons of water, is recommended.





UNITED STATES DEPARTMENT OF AGRICULTURE



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WM. A. TAYLOR, Chief



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THE EFFECT OF DIFFERENT TIMES OF PLOWING
SMALL-GRAIN STUBBLE IN EASTERN COLORADO.

By O. J. GRACE,

Assistant, Dry-Land Agriculture Investigations.

INTRODUCTION.

The data here presented have been obtained during the past six years at the Akron (Colo.) Field Station of the Bureau of Plant Industry. Though these data are from the Akron station only, they agree in the main with those obtained from other stations, and it is believed that the principles deduced are of general application in the Great Plains.

The time of plowing is one of the most frequently discussed subjects and one on which very few authoritative figures can be obtained. This is not due so much to a limited amount of experimental work as to the seemingly contradictory results obtained. In the following pages the major portion of the discussion will be confined to the time of plowing for spring wheat, which, although a crop of secondary importance in this region, was selected because a series of moisture determinations has been made in connection with its growth. Oats and corn have given similar results, so that wheat may be taken as representative of the spring crops.

The object of presenting these data at this time is not to advocate either spring or fall plowing, but to show, if possible, correlations between precipitation and time of plowing. Six years' records, with yields no more consistent than those here presented, are not sufficient justification for forming conclusions and laying down hard and fast rules in agriculture. In a climate where the precipitation is as erratic as it is in eastern Colorado there are very few farming operations which can be done successfully by rule of thumb, and this is especially true of any rule for time, depth, and method of plowing.

By many who have had little or no experience in actual farming in the semiarid regions of the West annual plowing is considered as

the most necessary of the cultural operations, but this is not substantiated either by the experience of many successful farmers or by the records from experimental work. A smooth, deeply plowed, well-harrowed surface looks well and gives the impression of carefully conducted farm operations, but may prove detrimental in crop production. The smooth, finely pulverized surface is readily subjected to blowing, and the loose, unpacked seed bed may be quickly dried by the rather free circulation of air through it. Stubble left on a field may give it an unkempt appearance, but at the same time may be of value in catching snow or in preventing the soil from blowing. There may be a great deal of misdirected labor expended in preparing a seed bed, which defeats the object sought rather than aids in the production of a crop.

Moisture is generally considered the most important factor in crop production in eastern Colorado. Its conservation is the primary object in cultivation. Experience has shown that on this soil weeds are the greatest robbers of moisture, and their control must always be considered. Stubble, weeds, and uneven ground are the common means of retaining snow and holding a large part of the winter precipitation. In deciding when a field shall be plowed, the question whether a greater amount of moisture will be accumulated by holding the snow that falls than will be dissipated by the growth of weeds must be paramount. It can best be decided by the man on the ground. In answering this question several factors must be considered, namely, the amount of moisture already in the soil that may be lost through weed growth, the probable time before the weeds will be killed by frost, the possibilities of increasing the water in storage in the soil by holding the snow that may come, the danger of soil blowing if the stubble and weeds are removed, and the distribution of the farm labor.

In the following pages the importance of these factors will be considered and the experimental evidence bearing upon them will be given. It is believed that a careful consideration of these data will assist the farmer in determining the best time to plow.

In order to interpret properly the following data it is necessary to consider the amount and distribution of precipitation during the time these investigations have been in progress. The precipitation records and crop yields of the six years from 1909 to 1914, inclusive, should be studied together if any correlation is to be seen between the distribution of precipitation and the time of plowing.

PRECIPITATION.

Table I gives the monthly precipitation for 10 years from 1905 to 1914, inclusive, which is the period covered by continuously recorded observations at Akron, Colo., both by the United States Weather

Bureau and the Bureau of Plant Industry. A study of these records shows the great variation in monthly and annual precipitation. The experimental data following are for the past six years, 1909 to 1914, inclusive. In two of these years the precipitation has been above the normal, as determined from the entire record. In 1909 the total was 2.2 inches less than the recorded maximum. In four years of the six it has been below normal, the precipitation of 1911 being the minimum recorded. Thus, in the six years we have had nearly the maximum and the minimum amounts of water that may be expected.

A heavy monthly precipitation usually means that a considerable amount falls at one time and penetrates to a depth where it is not lost by evaporation but can be used by plants. The exceptions to this are when the precipitation falls as torrential showers with a high percentage of run-off and shallow penetration, or when it comes as light snow, which is blown off. A light monthly precipitation indicates that the greater part of it falls as light showers or as snow flurries. Under such distribution most of the moisture is lost by evaporation and very little, if any, penetrates deeply enough in the soil to be held until used by the plants.

TABLE I.—*Monthly and annual precipitation and normal monthly and annual precipitation at Akron, Colo., 1905 to 1914, inclusive.*

[Precipitation record, in inches, for the years 1905 to 1909, inclusive, from the reports of the United States Weather Bureau.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1905.....	0.37	0.32	5.45	4.55	4.37	2.14	3.82	0.86	0.83	1.73	0.12	0	24.56
1906.....	.25	.26	1.51	4.22	3.32	1.20	2.46	1.26	1.00	1.90	1.56	0.08	19.02
1907.....	0	1 T.	.43	1.74	3.30	3.26	6.06	5.13	1.86	.02	1.00	.60	23.40
1908.....	0	.34	T.	1.70	3.57	2.35	3.40	1.62	.22	3.20	2.00	T.	18.38
1909.....	T.	1.38	3.06	.40	1.87	3.32	4.61	3.77	2.16	.78	.48	.55	22.38
1910.....	.05	.16	.26	3.96	2.06	1.38	1.47	3.72	3.81	.05	.12	.32	17.36
1911.....	.60	.44	.06	2.63	1.15	1.48	1.34	1.30	2.40	1.47	.28	1.36	14.51
1912.....	.28	1.43	.78	2.49	2.86	3.39	3.58	1.58	1.88	1.99	.18	.29	20.73
1913.....	.22	.40	1.57	2.19	1.44	1.35	1.85	1.14	2.08	.34	.30	3.67	16.55
1914.....	.03	.32	.20	4.01	1.46	3.54	1.66	1.05	.23	2.08	.10	.90	15.58
Normal ²	.18	.51	1.33	2.79	2.54	2.34	3.02	2.14	1.65	1.36	.61	.78	19.25

¹ T.=Trace.

² Normal precipitation, October to March, inclusive, is 24.8 per cent of the normal for the year.

In the consideration of the time of plowing, the great variation in time and amount of precipitation must be kept in mind. The winter precipitation is usually in the form of snow, and wind is an important factor in its local distribution. Heavy rainfall or snows that are not disturbed by wind may occur between November 1 and April 1, but as the ground is usually frozen the amount of moisture stored in the soil from them apparently would not be affected by the time of plowing. Generally, the greater part of the snowfall will be blown off of a fall-plowed field, while a considerable quantity will be held by stubble land.

Rains in August and early September invariably produce a growth of weeds, which usually exhaust the available soil moisture, a ton of Russian thistles using 65 per cent as much water as would be used in producing a ton of unthrashed wheat.¹ The loss of moisture which has penetrated to a greater depth than 3 inches after the weeds are dead in the fall and before growth starts in the spring is almost negligible, either from land fall plowed or from that covered with stubble. Light precipitation evaporates, unless it falls as snow which is blown into drifts until a considerable quantity has accumulated. As 10 inches of light snow is the equivalent of only 1 inch of rain and 1 inch of rain penetrates the surface soil to a depth of 6 inches, it will be readily seen that snows of 1 to 5 inches supply a very small amount of moisture, the greater part of which will be lost by evaporation.

While the normal precipitation of the six months from October to March, inclusive, is only 25 per cent of the normal annual, the highest recorded precipitation for any month, with one exception, is 5.45 inches in March, 1905. In five years of the ten recorded the precipitation in March has been less than 0.5 inch. The precipitation in the winter months has varied almost as much, in some years there being only snow flurries, while in others the snowfall sometimes totals 20 inches in a month. There has been a wider variation in the precipitation of the fall and winter, when moisture should be stored, than in the growing months.

Early fall rains will be used by weeds unless the land is cultivated. Heavy winter snows may occur, but they are likely to blow off the fields unless there is either stubble or an uneven surface to hold them. The time and method of cultivation, then, should be planned to prevent weed growth and still leave the soil or stubble in such a condition that it will hold the maximum of snow. The period when labor is available will also be an important factor in determining the time of plowing. When labor is scarce, cultivation other than plowing, which will kill weeds and can be done rapidly, may be resorted to. If this cultivation leaves the stubble on the surface or leaves the surface rough enough to hold snow, it may have even greater value than plowing. Disking or listing in the fall are the methods most commonly used.

EXPERIMENTAL WORK.

The experiments in crop-rotation and cultivation methods at Akron afford an opportunity for a number of comparisons between fall plowing and spring plowing. In this paper only the time of plowing after small grain will be discussed.

The practice has been to plow as early as practicable after harvest. The soil is then packed with a disk set straight and weighted. This

¹ See Briggs, L. J., and Shantz, H. L., Bulletin 284 of the Bureau of Plant Industry, entitled "The Water Requirement of Plants. I.—Investigations in the Great Plains in 1910 and 1911."

leaves the surface somewhat rough and tends to pack the furrow slice down on weeds or trash plowed under. The spring plowing for small grains has been done as early as weather conditions would permit and packed in the same manner as the fall plowing. Plowing for corn has been deferred until planting time.

Table II presents the results with spring wheat on fall-plowed and spring-plowed oat stubble in two similar 3-year rotations, Nos. 4 and 9, and from both the fall and the spring plowing of land continuously cropped to wheat. In this latter comparison the fall plowing is deeper than the spring plowing, but this difference has not apparently affected the results sufficiently to prevent their comparison in a study of the effects of time of plowing.

TABLE II.—*Annual and average yields of spring wheat from fall-plowed and spring-plowed plats at the Akron Field Station, 1909 to 1914, inclusive.*

Treatment.	Rotation No.	Yield per acre of grain (bushels).						
		1909	1910	1911	1912	1913	1914	Average.
Fall plowed:								
Oat stubble.....	4	10.6	4.6	6.7	18.8	0.3	13.8	9.1
Wheat stubble.....	B	10.3	6.2	4.1	20.7	.8	12.2	9.1
Average for fall-plowed plats.....		10.5	5.4	5.4	19.8	.6	13.0	9.1
Spring plowed:								
Oat stubble.....	9	14.3	6.3	.2	20.3	1.0	21.2	10.6
Wheat stubble.....	A	14.3	11.3	2.9	21.3	4.8	22.2	12.8
Average for spring-plowed plats.....		14.3	8.8	1.6	20.8	2.9	21.7	11.7
Gain or loss of spring-plowed over fall-plowed plats.....		3.8	3.4	-3.8	1.0	2.3	8.7	2.6

Table III presents in similar form the yields of oats from fall-plowed wheat stubble in rotations Nos. 1 and 3, from spring-plowed wheat stubble in rotation No. 2, and from both the fall and the spring plowing of land continuously cropped to oats.

TABLE III.—*Annual and average yields of oats from fall-plowed and spring-plowed plats at the Akron Field Station, 1909 to 1914, inclusive.*

Treatment.	Rotation No.	Yield per acre of grain (bushels).						
		1909	1910	1911	1912	1913	1914	Average.
Fall plowed:								
Wheat stubble.....	1	25.6	15.9	13.6	56.8	7.2	35.9	25.8
Do.....	3	15.6	13.0	14.8	40.0	4.7	36.6	20.8
Oat stubble.....	B	14.1	8.0	15.9	46.9	.6	36.9	20.4
Average for fall-plowed plats.....		18.4	12.3	14.8	47.9	4.2	36.5	22.4
Spring plowed:								
Wheat stubble.....	2	18.3	14.8	1.7	46.9	16.6	47.5	24.3
Oat stubble.....	A	21.1	10.9	4.3	41.9	6.6	39.4	20.7
Average for spring-plowed plats.....		19.7	12.9	3.0	44.4	11.6	43.4	22.5
Gain or loss of spring-plowed over fall-plowed plats.....		1.3	.6	-11.8	-3.5	7.4	6.9	.1

Table IV presents the yields of corn from fall-plowed oat stubble in two rotations, from spring-plowed oat stubble in one rotation, and from both fall-plowed and spring-plowed wheat stubble in one rotation each.

TABLE IV.—*Annual and average yields of corn from fall-plowed and spring-plowed plats at the Akron Field Station, 1909 to 1914, inclusive.*

Treatment.	Rotation No.	Yield per acre of grain (bushels).						
		1909	1910	1911	1912	1913	1914	Average.
Fall plowed:								
Oat stubble.....	1	26.4	7.9	9.3	29.1	6.0	16.7	15.9
Do.....	3	25.7	5.0	9.2	34.3	0	14.7	14.8
Wheat stubble.....	4	23.1	4.6	4.7	34.3	0	7.6	12.4
Average for fall-plowed plats.....		25.1	5.8	7.7	32.6	2.0	13.0	14.4
Spring plowed:								
Oat stubble.....	2	26.3	7.6	1.2	33.7	10.3	17.4	16.1
Wheat stubble.....	9	25.3	12.4	0	37.5	0	12.6	14.6
Average for spring-plowed plats.....		25.8	10.0	.6	35.6	5.2	15.0	15.4
Gain or loss of spring-plowed over fall-plowed plats.....		.7	4.2	-7.1	3.0	3.2	2.0	1.0

Table V presents the yield of winter wheat from two continuously cropped plats, the plowing of which was sometimes early and sometimes late.

TABLE V.—*Annual yields of winter wheat from plats plowed at different dates at the Akron Field Station, 1909 to 1914, inclusive.*

Plat.	Plowing date and yield of grain (bushels).											
	1909		1910		1911		1912		1913		1914	
	Plowed.	Yield.	Plowed.	Yield.	Plowed.	Yield.	Plowed.	Yield.	Plowed.	Yield.	Plowed.	Yield.
A.....	Sept. 14	14.5	Sept. 18	11.4	Sept. 3	1.7	Sept. 8	25.8	Sept. 20	3.3	Sept. 30	24.5
B.....	Sept. 22	12.9	..do....	10.3	Aug. 12	6.8	Aug. 15	26.7	Sept. 18	2.0	..do....	24.8

SOIL MOISTURE.

Some of the factors determining the yields of small grain are apparent to the casual observer. One of these is the greater number of weeds growing with the grain crop on fall-plowed land at the Akron Field Station.

Another factor not so readily seen is the moisture content of the soil at the time of seeding. A knowledge of the exact percentage of moisture in the soil is not necessary. While the water-carrying capacities of soils vary with their composition and compactness, it may be taken as a working hypothesis that on the hard land of eastern Colorado the relative depths to which water has penetrated on different fields is a fair approximation of the relative amounts of

water available on them. For example, if one field is found to be wet to a depth of $1\frac{1}{2}$ feet and a second is wet to a depth of 3 feet it may be assumed that the second field has approximately twice as much water in it as the first field. In the discussion of soil moisture as related to time of plowing it is not necessary to consider the hygroscopic moisture, which is not available to the plants.

Wheat plants at Akron readily root to a depth of 5 feet if the soil is wet from the surface to that depth and if there is not a more easily obtained supply nearer the surface. This soil will hold an average of $1\frac{1}{2}$ inches in each of the upper 5 feet, so that $6\frac{3}{4}$ inches of precipitation may be stored for the use of the crop. This would be sufficient under favorable wind and temperature conditions to produce a crop of 10.7 bushels of wheat per acre.¹

In order to study the relative efficiency of different times of plowing in the accumulation of moisture in the soil and the relation of the moisture in storage to crop production, moisture determinations have been made at more or less regular intervals.² A continuous record of the moisture content is available for only two plats under discussion. These are plats A and B, continuously cropped to spring wheat, and are probably representative in their moisture relations of all spring-plowed and fall-plowed plats, plat A being continuously spring plowed and plat B continuously fall plowed.

In Table VI are presented the data obtained in making the moisture determinations on these plats. The moisture content is shown in percentages of the dry weight of the soil. For example, 10 per cent means that for every 100 pounds of dry soil there are 10 pounds of water. In the table are shown the total water content at the time of sampling, the nonavailable water, or that which can not be utilized by the plants, and the water available for the use of the plant.

The total water content needs little explanation. It is determined directly by weighing the sample of soil, drying it thoroughly, reweighing, and determining the loss in weight. The difference in weight represents the amount of water.

As water from the soil is used by the crop and the soil becomes drier, a point is reached below which the plants can obtain no more water. This point is called the "minimum point of exhaustion," and the amount of water remaining in the soil below this point is termed "nonavailable." The minimum point has been determined by observing the behavior of the crop on the plat and by frequent sampling. By continuing such study through several years the minimum point can be determined quite accurately.

¹ See Briggs, L. J., and Shantz, H. L., *op. cit.*

² Moisture determinations are made through the cooperation of the Office of Dry-Land Agriculture and the Biophysical Laboratory.

TABLE VI.—*Total, nonavailable, and available water in spring-wheat plats A and B on different dates at the Akron Field Station.*

[Data in percentages of dry weight of soil.]

Plat and depth.	1908	1909		1910		1911			1912			1913			1914	
	Aug. 27	Apr. 7	Aug. 25	Mar. 17	July 18	Apr. 8	Aug. 15	Oct. 30	Apr. 9	Aug. 7	Oct. 29	Apr. 5	July 24	Oct. 2	Mar. 24	July 20
Plat A (spring plowed):																
1 foot { Total	9.4	25.8	15.3	20.7	6.9	10.8	7.9	11.7	21.8	14.3	14.8	19.2	18.0	11.7	19.1	8.8
Nonavailable	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Available	2.4	18.8	8.3	13.7	0	3.8	.9	4.7	14.8	7.3	7.8	12.2	11.0	4.7	12.1	1.8
2 feet { Total	11.8	21.7	15.2	17.5	11.5	12.5	11.3	11.5	22.9	13.9	12.6	13.8	14.1	12.3	17.6	11.2
Nonavailable	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Available	.3	10.2	3.7	6.0	0	1.0	0	0	11.4	2.4	1.1	2.3	2.6	.8	6.1	0
3 feet { Total	9.6	12.7	11.4	12.5	10.2	10.4	9.0	9.3	19.3	10.7	10.1	10.7	9.5	9.3	10.0	9.1
Nonavailable	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Available	.3	3.4	.1	1.2	.9	1.1	0	0	10.3	1.4	.8	1.4	.2	0	.7	0
4 feet { Total	9.2	11.2	10.4	9.8	9.4	8.0	7.9	14.2	10.4	8.9	9.5	8.9	8.0	8.0	8.2	8.3
Nonavailable	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Available	.2	1.2	3.2	2.4	1.8	1.4	0	6.2	2.4	.9	1.5	.9	.0	.0	.2	.3
5 feet { Total	8.6	11.7	9.7	9.8	10.6	8.3	8.0	15.6	9.5	9.6	9.9	10.0	8.7	8.2	8.2	8.5
Nonavailable	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Available	.4	3.5	1.5	1.6	2.4	.1	0	7.4	1.3	1.4	1.7	1.8	.5	0	.3	.3
6 feet { Total	7.6	11.7	9.1	9.6	7.3	8.5	8.8	12.3	11.7	11.0	10.0	10.6	8.5	8.1	8.1	8.1
Nonavailable	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Available	0	4.1	1.5	2.0	0	.9	1.2	4.7	4.1	3.4	2.4	3.0	.9	.5	.5	.5
Plat B (fall plowed):																
1 foot { Total	9.6	25.3	14.5	16.0	6.4	13.6	9.9	14.4	19.4	10.8	17.6	15.9	12.8	10.5	17.6	7.4
Nonavailable	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Available	2.6	18.3	7.5	9.0	0	6.6	2.9	7.4	12.4	3.8	10.6	8.9	5.8	3.5	10.6	.4
2 feet { Total	10.8	22.4	13.2	15.5	11.9	18.2	11.5	11.5	20.5	10.5	15.0	11.3	11.6	10.1	13.7	9.3
Nonavailable	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Available	0	10.9	1.7	4.0	.4	6.7	0	0	9.0	0	3.5	0	.1	0	2.2	0
3 feet { Total	8.6	14.9	10.1	11.8	9.8	14.8	9.6	9.2	14.2	8.1	9.7	8.1	8.6	7.2	9.5	8.0
Nonavailable	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Available	0	5.6	.8	2.6	.5	5.5	.3	0	4.9	0	.4	0	0	0	.2	0
4 feet { Total	11.1	9.7	9.8	9.3	10.9	9.8	8.2	9.4	8.7	8.6	7.4	8.1	6.5	7.6	7.0	7.0
Nonavailable	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Available	2.9	1.5	1.6	1.1	2.7	1.6	0	1.2	.5	.4	0	0	0	0	0	0
5 feet { Total	10.0	8.1	9.1	8.7	9.5	10.4	8.9	8.4	9.7	9.1	7.5	8.2	6.6	7.5	6.4	6.4
Nonavailable	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Available	1.9	0	1.0	.6	1.4	2.3	.8	.3	1.6	1.0	0	.1	0	0	0	0
6 feet { Total	6.7	7.0	8.6	7.2	8.0	10.0	8.1	7.8	7.7	8.3	7.0	7.0	6.7	6.5	6.2	6.2
Nonavailable	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Available	0	0	1.6	.2	1.0	3.0	1.1	.8	.7	1.3	0	0	0	0	0	0

The water available for the use of the plant is computed by subtracting the nonavailable water from the total water content. It is the available water in which the farmer is interested. This, together with the rainfall during the growing season, represents the total water supply for the production of crops. In order to show more clearly the available water, figure 1 has been prepared. In it are presented graphically the relative amounts of available water in each foot-section, as shown in Table VI. At the left of the figure is shown the depth represented in foot-sections from 1 to 6 feet. The dates the determinations were made are shown at the top of each column. Each division of the black column represents the percentage of water in that foot-section available for the use of the plants on that date.

As already stated, the percentages are computed on the dry weight of the soil, and, as the weight of the soil in the first foot is less than in those below, the percentage of moisture must be higher to indicate an equal amount of water. For example, the percentage of moisture on April 9, 1912, on plat A in the first foot was higher than for the second, but the actual amount of water in each of the 2 feet was the same. The weight per cubic foot of the lower 5 feet is nearly the same, so that a comparison of moisture percentages is also a direct comparison of moisture content.

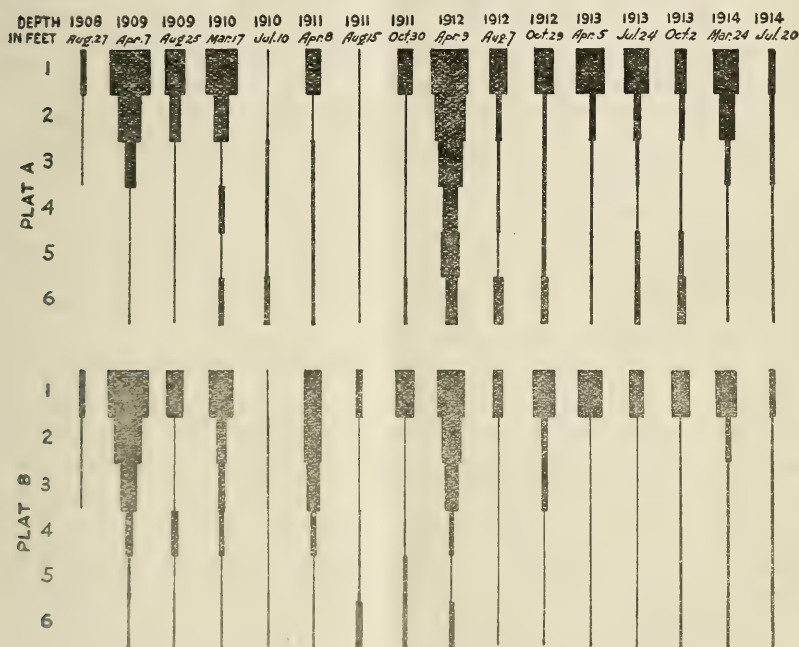


FIG. 1.—Graphs showing the amounts of water available to wheat in each of the upper 6 feet of soil at certain dates of sampling at the Akron Field Station, for the years 1908 to 1914, inclusive. Plat A is spring plowed, plat B is fall plowed, and both are continuously cropped to spring wheat.

A small percentage of moisture in any foot does not necessarily mean that the moisture was evenly distributed through that foot. It may have been contained in a few inches of one foot. The determinations of October 30, 1911, show 4.7 per cent in the first foot of plat A, all of which was probably in the upper 8 inches. The soil is usually exhausted of available moisture at the time the small grain is harvested. One exception to this was plat A, on August 7, 1912. The summer precipitation had been so heavy that all the water in the soil on April 9, 1912, had not been needed in the production of the crop. The spring sampling of April 7, 1909, showed a little higher moisture content in plat B than in plat A. The difference was in the third and fourth feet.

The sampling of April 17, 1910, shows a higher moisture content in the first and second feet of plat A than in the corresponding feet in plat B.

The sampling of April 8, 1911, shows about six times as much water in plat B as in plat A.

On April 9, 1912, plat A contained more than twice as much available moisture as plat B. As the greater part of the moisture in plat A was due to snow held by the stubble, it is probable that the snow melted and the stubble refilled several times during the winter, and as the increase in the moisture in this plat from October 30, 1911, to April 9, 1912, was greater than the precipitation during that period, the snow must have drifted on to this plat from adjacent fields.

The moisture in the soil on April 15, 1913, was all in the first foot. The amount in plat A was slightly greater than in plat B.

In the late fall of 1913 there was but little moisture in the first foot of plat B. This was slightly increased during the winter of 1913-14. Plat A contained much less water at the time of sampling in the late fall. There was an increase in the amount in the first, second, and third feet during the winter. The grain yield from plat A was 82 per cent higher than that from plat B, while the total yield of straw and grain was only 16 per cent higher.

In 1909, 1910, 1913, and 1914 there were but small differences in the moisture content of the two plats at the time of seeding, and in those years the better yields were from spring plowing. In 1911, when there had been a heavy precipitation the previous August, there was a very pronounced difference in favor of fall plowing. In 1912, when there was moisture to the depth of 6 feet in plat A and 3 feet in plat B, the yields were nearly equal. This was chiefly due to the heavy summer precipitation, which supplied the crop without its having to depend on stored water.

A comparison of annual yields from spring plowing and fall plowing shows considerable differences every year, except in 1912, when the summer precipitation was high enough to produce good yields with little or no stored moisture. In five years out of the six wheat and corn have averaged better on spring plowing than on fall plowing. In those five years there is not an instance where either the spring-plowed wheat or corn plats dropped below the average of the fall-plowed plats.

The oat yields each season show a slightly greater variation than do the yields of either wheat or corn, but still they must be considered consistent. In four of the six years the average yields from the spring-plowed plats were higher than those from the fall-plowed plats. These were the years when spring plowing gave the better results with both wheat and corn. The only year that oats gave a higher yield

from fall plowing, when wheat and corn gave higher yields from spring plowing, was 1912. This was a year when the yields of oats were near the maximum in that locality for the variety used—Kherson. In only one year (1911) out of the six did fall plowing give the best results with all three crops. This also was the year in which early fall plowing gave a marked increase over late plowing with winter wheat.

The yields of winter wheat on plats A and B, presented in Table V, are of interest. Three years out of the six one plat was plowed earlier than the other. The condition of the surface of the plats during the winter was the same, both being devoid of stubble and equally level.

The only important difference in treatment was the time of plowing. In all three instances the higher yields have been on the earlier plowing. The only marked difference, however, was in 1911, when the earlier plowing had been done immediately after heavy rains and a large growth of weeds occurred on the later plowed plat before it was plowed. In the three years when there was no difference in time of plowing there was no difference greater than 1.3 bushels in yields. While this was a difference of more than 60 per cent, it will be noted that both plats were practically failures in that year (1913). In the six years the only marked difference in yields was in 1911, when the plowing was done 22 days earlier on plat B than on plat A and plat B yielded 5.1 bushels more than plat A. Except when early plowing had stored moisture by stopping weed growth, there was no marked difference in yields. The late fall plowing usually lost available moisture by weed growth, which was not offset by a greater winter accumulation, as in spring plowing.

In studying each year separately it is necessary to consider the precipitation. Data on the moisture content of the soil in the fall and spring and at harvest time will aid in giving an idea of the relative importance of fall and winter precipitation and the amount used by the crop.

Figure 1 shows that in the fall of 1908, up to which time the plats had had uniform treatment, there was no moisture in the soil available to plants. August and September were very dry and plowing was not done until the weeds had been killed by frost. While there was heavy precipitation in November, 1908, and in March, 1909, the increase in moisture content was practically the same, the third foot of both plats being partially filled. Plat A gave a yield of 14.3 bushels, and there was still some moisture available at the time of harvest. The greater number of weeds growing with the wheat in plat B probably accounts for the greater loss of moisture and the smaller yield. This statement is borne out by the yields of corn, which were practically the same from both the spring and the fall

plowing. The corn was given clean cultivation. The spring-plowed wheat plats averaged 3.8 bushels and the spring-plowed oat plats 1.3 bushels per acre more than the fall-plowed plats.

The heavy rains in August and early September in 1909 prevented thrashing and delayed fall plowing until the latter part of September. By that time the heavy growth of weeds had used the soil moisture resulting from the precipitation of August and September, and plat B plowed up dry and lumpy. No moisture determinations were made at this time, but it is only fair to assume that plat A was equally dry, as it also had produced a heavy growth of weeds. In the spring of 1910 the moisture content of plat A was decidedly greater in the first and second feet and slightly greater in the third foot than it was in plat B. This increase in moisture content was due to the snow held by the stubble on plat A. At harvest time the moisture was exhausted in both plats, but plat A gave a yield of 11.3 bushels and plat B yielded 6.2 bushels.

The small difference in moisture content in the spring could not account directly for the difference in yields, but the slightly larger amount of moisture in plat A may have caused a quicker growth, which crowded out the weeds. All three crops were better on spring than on fall plowing. The corn, in which weeds were not a factor in determining the yield, showed a difference in favor of spring plowing.

As the moisture in both plats A and B was exhausted at harvest time, their moisture content was probably the same when plat B was plowed, August 12, 1910.

The early plowing of plat B prevented weed growth on it, and the greater part of the heavy rains of August and September was stored until the following season. Practically all the water from these rains was used in the fall by a heavy growth of weeds that occupied the plats which were to be spring plowed. Light precipitation during the winter of 1910-11 added very little water to the soil; consequently the spring-plowed plats had much less moisture in the spring than the fall-plowed plats. The yield was 4.1 bushels of wheat from plat A and 15.9 bushels from plat B. All the moisture had been used from both plats. Every fall-plowed plat gave a better yield than was obtained from any spring-plowed plat.

Plat B was plowed on August 16, 1911, immediately after a rain of 1 inch. There were only light rains during August and September, which slightly increased the moisture content of the first foot in plat B but made no change in plat A. The heavy snows of February and March were held by the stubble on plat A. In melting they filled its soil to a depth of at least 5 feet. There was no change below the third foot in the water content of plat B.

The precipitation of the growing season was so heavy that none of the crops suffered from lack of moisture. The yields from fall plow-

ing and spring plowing were nearly equal. At harvest there was a small amount of moisture in plat A to a depth of 6 feet, while that in plat B had been exhausted.

The remainder of the moisture in plat A was used by weeds, and at the time plat B was plowed, September 18, 1912, the moisture in both plats was equal. In the spring of 1913 the first determination showed there had been a slight increase in the water content of plat A to a depth of 3 feet, while there had been an increase in only the first foot of plat B. The water in plat B was so nearly exhausted by the first week in June that the crop was burned beyond recovery, while plat A had water enough, supplemented with a light precipitation, to produce 4.8 bushels of wheat. The yields from all plats were very low, but the average yield was higher for all three crops on spring plowing.

The light precipitation of August and September, 1913, did not put the soil in condition for plowing until October 14. There was very little weed growth in the fall and the sampling of October 2 shows very little stored water. The water content of plat A in the spring was twice as great as that of plat B, but neither had an appreciable amount of available water below the second foot. While there was but a small difference in the moisture content of the two plats, the yield of grain from plat B was only 55 per cent of that from plat A. The yield of straw was the same from each. The slight difference in water content in favor of plat A, with the smaller number of weeds in the grain and a normal precipitation during the growing season, had enabled it to produce a good crop of grain, while plat B had dried up before maturing.

SUMMARY.

The average yields from spring and from fall plowing show that the blind following of a rule prescribing any particular time of plowing might cause a reduction as often as it does an increase in the yields of the three spring crops of wheat, oats, and corn. The very small difference in yield each year from plats plowed at the same time, when compared with the greater difference from plats plowed at different times, indicates that the time of plowing is one of the most important of the controllable factors in crop production.

The great variation in the time and amount of precipitation is the important climatic characteristic of this region in eastern Colorado that must be kept constantly in mind when considering the time of plowing. No dependence can be placed on a heavy precipitation in August and September, yet it frequently occurs. When there is such precipitation, measures should be taken to conserve it. Weeds being the important factor in its dissipation, cultivation to destroy them should be given as soon as possible after the occurrence of rains in

those months. Precipitation that comes after the weeds are killed by frost in the fall is as well stored by soil covered with dead weeds as by a turned furrow. Usually there is greater increase in moisture content in the spring-plowed plats during the winter than there is in the fall-plowed plats. This is due to the snow held by the stubble on the land which is to be spring plowed. Sometimes there is a very decided increase of the moisture in the spring-plowed land, which, with a normal summer precipitation, makes a great difference in yields.

Moisture content in the spring is but one of the factors in the production of grain crops. Weeds growing with the crop may use enough water to decrease the grain yield materially. Fall plowing at the Akron station is especially favorable to weeds starting with the grain. Plowing in the spring thoroughly eliminates the weeds and, if done immediately before seeding, gives the grain crop the start of them. No other cultivation is so effective in destroying weeds as plowing. The ideal cultivation would prevent weed growth in the fall, leave the land in such a condition that it would retain the maximum of snow in the winter, and retard the germination of weed seed until the crop starts in the spring.

Early fall plowing effectively destroys weeds which use the early fall precipitation, but it does not leave the land in condition to retain the snow in the winter and it gives the weeds an opportunity to start before the crop. Spring plowing leaves the stubble to retain snow and reduces the number of weeds in the growing crop, but it does not prevent the loss of moisture by weed growth in the fall.

In deciding the time to plow, the advantages and disadvantages of both spring plowing and fall plowing must be taken into consideration. Heavy rains in August indicate that fall plowing should be done, as the gain in moisture during the winter by stubble land probably would not equal the loss by weeds in the fall. If only light rains occur, their loss probably would be more than offset by the greater quantity of snow held by the stubble during the winter and the reduction of the weeds in the crop. Spring plowing would then be the better. The availability of labor in the fall will influence the amount of plowing done, but a greater effort should be made to do the plowing if there is heavy precipitation than if it is light. The only advantage in late fall plowing is that the amount of spring labor in preparing a seed bed is reduced. This advantage may be offset by a reduction in yield.

CONCLUSIONS.

(1) Early fall precipitation is used by weeds if land is left uncultivated until spring.

(2) Stubble prevents much of the winter snow from being blown off. The increase in soil moisture from this source usually more

than compensates for the loss by weed growth of the precipitation of August and September, when such precipitation is light.

(3) Late fall plowing does not prevent the loss of early fall precipitation through weed growth, but it does destroy stubble, which would aid in holding winter precipitation.

(4) If heavy rains occur in August or September, plowing should be done immediately after they cease. If this can not be done, or if heavy rains do not occur, the land should be left in stubble until the following spring.

(5) The ideal cultivation would prevent weed growth in the fall, leave the land in condition to retain the maximum quantity of snow in the winter, and thoroughly destroy small weeds immediately before seeding. Possibly this may be accomplished by disking in the fall and plowing in the spring, or listing in the fall and bursting the ridges in the spring may prove practicable.

(6) In deciding when a field in this part of eastern Colorado should be plowed, the question whether a greater amount of water will be accumulated from snow than will be dissipated by weeds is paramount and must be decided by the man on the ground.

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L. O. HOWARD, Chief



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PROFESSIONAL PAPER

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THE SHARP-HEADED GRAIN LEAFHOPPER.

By EDMUND H. GIBSON, *Entomological Assistant, Cereal and Forage Insect Investigations.*

INTRODUCTION.

The sharp-headed grain jassid or leafhopper (*Draeculacephala molipes* Say) has long been known to infest cereal and forage crops, principally grains and grasses. It is probably one of the most commonly observed insects of the farm, ranging throughout practically the entire United States. However, as Prof. Herbert Osborn remarks,¹ "it seems to have received much less notice from the economic standpoint than it merits."

The observations and facts set forth in this paper are the result of an entire year's work on the species in the Salt River Valley of Arizona during 1914, together with occasional observations elsewhere. With these data have been included the results of various miscellaneous observations made by other assistants engaged in cereal and forage insect investigations in the Bureau of Entomology.

The most extended account of this species previously published is included by Prof. Herbert Osborn¹ in Bulletin 108 of the Bureau of Entomology, and the aim of the present paper is to supplement Prof. Osborn's excellent treatise from which the author has freely quoted. The sharp-headed grain jassid was described by Say in 1831, mentioned by Dr. Asa Fitch in his list of insects in 1851, and was commented upon by Prof. P. R. Uhler in 1884. Prof. H. Garman describes it as a corn pest in 1890 in the second Annual Report of the Kentucky Agricultural Experiment Station, and Prof. Osborn gave an account of the species in Bulletin 22, Division of Entomology, U. S. Department of Agriculture, and in 1891, 1892, and 1897 added materially to the knowledge of the species, his account in 1912 being the last published treatise on the species.

¹ Osborn, Herbert. Leafhoppers affecting cereals, grasses, and forage crops. U. S. Dept. Agr., Bur. Ent., Bul. 108, 123 p., 29 fig., 4 pl., Sept. 12, 1912. See p. 56.

NOTE.—This paper is of interest to entomologists throughout the United States.

ECONOMIC IMPORTANCE AND MODE OF INJURY.

The economic importance of the Jassidæ has never been fully appreciated by the farmer and planter, nor have these insects been given the attention which they deserve, even by entomologists. Especially is this true of the sharp-headed grain jassid, one of the most widely distributed species with a great variety of food plants. While it probably may not become a destructive pest over wide areas, there is always the possibility of local outbreaks which may cause serious injury and temporary losses, as exemplified by the attack upon 180 acres of corn on the farm of Dr. O. R. Stewart, Palatka, Ark., during July, 1912. It no doubt occurs in small numbers every year over its entire range of distribution and causes secondary injury to grain and pasture grasses by attacking vigorous growing plants, hindering and interfering with their growth and development, and already weakened and unhealthy plants, hastening their death or permanently dwarfing them.

The greatest damage inflicted by the sharp-headed leafhopper is to young and tender grain crops by the feeding of nymphs and adults during the fall and early spring months. To corn and other crops the greater damage is done during the summer months. Because alfalfa is of such rapid growth the apparent injury to the crop will probably always be very slight.

There are three classes of injury, the most important of which is the direct injury caused by the feeding of nymphs and adults, in puncturing leaf and stem tissue and sucking the juices therefrom. An occasional feeding puncture in a leaf or stem would not of itself do appreciable harm, but when there is a concentrated attack upon a plant by from 10 to 50 nymphs or adults the injury becomes appreciable. In many instances the author has observed leaves withered throughout from this cause. The early stages of injury are indicated by a yellowing of the tissue around the feeding punctures, which are in themselves so small as to be hardly visible to the naked eye. Following the yellowing there is a drying and deadening of tissue which turns reddish brown, giving the leaf or stem a spotted appearance.

Ordinarily the feeding of the nymphs is more injurious to a plant than that of the adults because usually there are to be found a great many more nymphs than adults on the same plant. It is believed that nymphs, after hatching from the eggs, often remain on the same plant during the first two or three instars. The feeding of the nymphs in grain is practically limited to the throats of the plants; however, they will feed on almost any tender or succulent part. In the case of alfalfa the feeding is done on the underside of the leaves and upon young tender stems. The adults feed freely upon

the stems and leaves, especially along the midribs, of grains, grasses, and alfalfa. Their feeding causes very young alfalfa plants to grow slim and spindling.

Another form of injury is produced by the adult female in puncturing and constructing in leaves and stems the pockets for oviposition. A slit is made in the leaf or stem, and the eggs are thrust through this slit under the epidermis. These egg pockets cause a distortion of the surrounding plant tissue which later turns yellow. When four or five egg pockets are made in a single leaf of a young grain plant the injury resulting to the leaf is quite marked, and when several leaves on the same plant, as is often the case, are so affected, the entire plant is bound to be more or less injured.

The third mode of injury is caused by spores of fungous diseases gaining entrance to the plant tissue through the feeding punctures and egg-pocket slits. It is more than probable, but as yet has not been positively determined, that jassids themselves carry and disseminate the spores of rust and other fungous diseases.

DISTRIBUTION.

As Prof. Osborn has noted,¹ this jassid has an extremely wide distribution. In this country it ranges from the Atlantic to the Pacific and from the strictly boreal portions of Canada south into Mexico. It has been recorded by assistants of the Bureau of Entomology from 35 States, representing all sections of the United States excepting New England, where, although in all probability it occurs, no available records show its presence.

FOOD PLANTS.

The author has taken the nymphs and adults in large numbers from wheat, barley, oats, alfalfa, bur clover (*Medicago denticulata*), sour clover (*Melilotus indica*), Johnson grass (*Sorghum halepense*), wall barley (*Hordeum murinum*), and many other native grasses of the south and southwest. The adults alone have been observed feeding upon kafir corn, sorghum, cowpeas, vetch, and Bermuda grass. In addition to this list Prof. Osborn reports¹ having taken the species from rye, bluegrass, and brome grass. Other assistants of the Bureau of Entomology have noted the species as feeding on corn and timothy. It is very likely that a complete list of food plants would include several other cultivated crops and innumerable weeds.

DESCRIPTION.

The following is a copy of the technical description (*Tettigonia mollipes*) by Say, published in 1831:

Body yellow; head elongated, acute before; beneath the eyes a brown line, which is contained on the pectus; thorax green, a broad anterior and lateral yellow margin;

¹ Op. cit., p. 57.

scutel greenish-yellow; hemelytra green; nervures paler; exterior and apical margins pale yellow or whitish; a pale yellowish, capillary, oblique line from the humerus to the inner margin; tergum black-purple, lateral edge and tip yellow.

Length to the tip of the hemelytra over three-tenths of an inch.

A common species.

A simple description which will enable the farmer or uninitiated to recognize the species in its several stages is given below:

ADULTS.

(Fig. 1, *a-f.*)

Color bright grass-green, head very sharply pointed, of a slightly lighter green than body. Face marked with oblique lines. Males noticeably smaller than females, and with black venter. Venter of female lighter than wing covers.

EGGS.

(Fig. 1, *k.*)

The eggs are white; when first deposited they are rather transparent, later becoming opaque. They are irregularly elongate in form, comparatively blunt at both ends, and about three times as long as wide. The head end of the egg is somewhat bulging. Eyes of the immature nymph show through the eggshell as red spots a few days before hatching takes place. Table I, taken from the notes of Mr. V. L. Wildermuth, an assistant of the Bureau of Entomology, gives the egg measurements.

TABLE I.—Measurements of eggs of the sharp-headed grain leafhopper.

Egg.	Length.	Maximum width.	Minimum width.
	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>
1.....	1. 40	0. 35	0. 15
2.....	1. 25	. 40	. 10
3.....	1. 40	. 40	. 125
Average.....	1. 35	. 38	. 125

NYMPHS.

(Fig. 1, *g-j, l.*)

In general the nymphs resemble adults in shape and color, the most noticeable difference being in absence of wings and wing covers, and in size.

First-instar nymphs (fig. 1, *l*).—Color light yellow-green, uniform but somewhat darker on dorsal side of last two abdominal segments. Legs a cottony white. One dorsal stripe of lighter yellow running

entire length of body from vertex to tip of abdomen. Two dark spots at rear of head, one on either side of dorsal stripe. No hairs

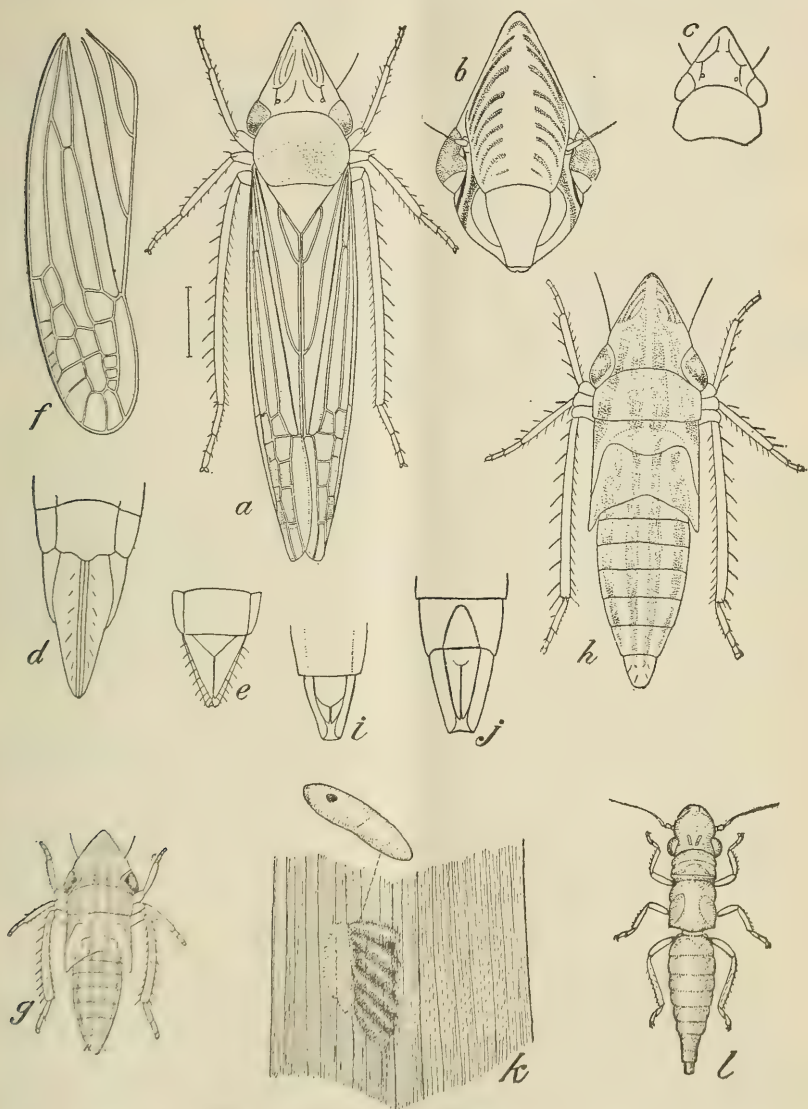


FIG. 1.—The sharp-headed grain leafhopper (*Draculacephala mollipes*): a, Adult from above; b, face; c, vertex and pronotum; d, female genitalia; e, male genitalia; f, wing; g, h, nymphs; i, anal segment of last-stage nymph, showing genitalia of male; j, anal segment of last-stage nymph, showing female genitalia; k, eggs inserted in blade of wheat; l, freshly-hatched nymph. a k, Enlarged; l, greatly enlarged. (a-h, From Osborn; i-l, original.)

or spines. Head very blunt, in contrast with nymphs of later instars. Average 1.5 mm. in length.

Second-instar nymphs.—Average length 2.5 mm. Head more pointed or acute. Black-line facial markings becoming distinct. Light median dorsal stripe remaining.

Third-instar nymphs.—Average length 3 mm. Spines on hind legs prominent. More mottled with gray markings. Head larger but not more pointed or acute. Dorsal stripe remains, extending to tip of abdomen. Eyes darker and more prominent. First indication of wing pads.

Fourth-instar nymphs.—Average length 4.2 mm. Head more pointed. Black-line facial markings very distinct. Dorsal stripe remaining. Spines on legs prominent. Wing pads larger.

Fifth-instar nymphs.—Average length 5 mm. Body darker green. Eyes slightly lighter green than body color. Hairs on tip of abdomen. Head slightly more pointed. Wing pads well developed and opaque.

COLOR FORMS OF ADULTS.

In 1913 Mr. Wildermuth noted many adults of a brown color. Thinking these might be another species specimens were sent to Prof. Osborn for determination, who replied to the effect that "the brown form is a variation of the green form which is usually the most common." The writer observed many of this brown form during January and February, 1914, but was unable to find a single brown individual during the spring and summer months. All adults reared from brown parents were entirely green and remained a true green until death. Because brown-form adults have been found only among the wintering adults the writer is inclined to believe that the brown coloration is due to a fading of the green pigment caused by prolonged life, as is the case with wintering adults, or by extreme weather changes. Recently Prof. Osborn has remarked that his "collection of brown individuals at El Paso, Tex., March 3, 1910, bears out the supposition that these may be old and faded specimens."

LIFE HISTORY AND HABITS.

As with all jassids, this species has three stages in its life cycle, namely, egg, nymph, and adult. The adult female deposits her eggs in pockets in leaves and stems, and these eggs hatch under Arizona conditions in from 3 to 35 days, depending upon the temperature. Through a series of five molts the nymphs increase in size, develop, and with the last molt transform to the adult. The length of the nymphal stage, as with the egg stage, depends largely upon the temperature, averaging 30 days in Arizona.

NUMBER OF GENERATIONS.

The number of generations a year will vary in different parts of the country according to the various climates, and is likely to fluctuate from year to year in accordance with seasonal variations. Prof.

Osborn remarks that in Ohio "there are clearly two distinct generations annually." In the Southern States, where there are more generations, these are not so clearly distinct, due to an overlapping of the three stages during the summer months. Because of this overlapping of the egg, nymphal, and adult stages it is very difficult to determine the exact number of generations from field observations. By the use of breeding cages it was possible to determine that there were six distinct generations for southern Arizona during 1914. The cage experiments checked up very closely with field observations. Thus the number of generations may vary from two to six.

For southern Arizona the first spring generation extended over February, March, and April; the second, over May and the first half of June; the third, over the last half of June and July; the fourth, over August; the fifth, over September; and the sixth, over October and November, the adults of the sixth generation living over winter and ovipositing in February for the following spring generation.

LENGTH OF EGG STAGE.

The length of the egg stage in southern Arizona was found to vary from 3 to 35 days, depending upon the temperature, the average being 12 days. Table II gives the length of the egg stage, with the corresponding temperatures, and plainly shows that the length is materially shortened during the summer months.

TABLE II.—*Length of the egg stage of the sharp-headed grain leafhopper, Tempe, Ariz., 1914.*

Number of eggs.	Date of oviposition.	Date of hatching.	Length of egg stage.	Average mean temperature during egg stage.
			<i>Days.</i>	<i>° F.</i>
4	Feb. 4	Mar. 11	35	59.0
16	Feb. 13	...do....	26	61.7
6	Feb. 19	Mar. 12	21	67.4
6	Mar. 5	Mar. 20	15	65.9
3	Apr. 5	Apr. 20	15	70.4
5	May 8	May 16	8	74.3
7	May 11	May 18	7	74.3
8	...do....	May 16	5	74.1
10	June 19	June 28	9	85.0
9	July 29	Aug. 1	3	93.0
14	Aug. 28	Sept. 2	15	82.8
20	Oct. 1	Oct. 5	4	71.0
Average.....			12.75	

SUMMARY, SHOWING CONDENSED AVERAGES.

When length of egg stage averaged—	The average mean temperature was—
<i>Days.</i>	<i>° F.</i>
27.3	62.7
15.0	68.1
8.0	77.8
4.2	80.2

From the notes made by Mr. V. L. Wildermuth at Tempe, Ariz., during February and March, 1913, the length of the egg stage is shown in Table III to be practically the same as found by the writer for those months.

TABLE III.—Length of egg stage of the sharp-headed grain leafhopper, Tempe, Ariz., February and March, 1913.

Date of oviposition.	Date of hatching.	Length of egg stage.
		Days.
Feb. 21.....	Mar. 29	36
Feb. 25.....	Mar. 18	21
Feb. 27.....	Mar. 22	23
Feb. 27.....	Mar. 25	26
Average.....		26.5

LENGTH OF NYMPHAL STAGE.

As with the egg stage, the length of the nymphal stage varies with the temperature. Prof. Osborn's observations in Iowa show that the nymphal stages extend over from early spring until the latter part of June and from the second week in August until nearly winter. Where the temperatures are higher and the summer season more prolonged the length is considerably shortened. The observations at Tempe, Ariz., show that the average length varies from 20 to 51 days, according to the temperature. Table IV gives the length of the nymphal stage of each of the six generations and the length of each instar.

TABLE IV.—Length of nymphal stage of the sharp-headed grain leafhopper, Tempe, Ariz., 1914.

FIRST SPRING GENERATION, MARCH, APRIL, AND MAY, 1914.

Nymph emerged from egg.	Date of first molt.	Length of first instar.	Date of second molt.	Length of second instar.	Date of third molt.	Length of third instar.	Date of fourth molt.	Length of fourth instar.	Date of fifth molt.	Length of fifth instar.	Total length of nymphal stage.
		Days.		Days.		Days.		Days.		Days.	Days.
Mar. 4	Mar. 14	10	Mar. 25	11	Apr. 4	10	Apr. 13	9	Apr. 23	10	50
Do....	Mar. 10	6	Mar. 18	8	Mar. 30	12	Apr. 8	9	Apr. 20	12	47
Mar. 10	Mar. 23	13	Apr. 2	10	Apr. 8	6	Apr. 14	6	Apr. 23	9	44
Do....	Mar. 19	9	Mar. 28	9	Apr. 6	9	Apr. 13	7	Apr. 21	8	42
Mar. 8	Mar. 17	9	Apr. 1	15	do....	5	Apr. 11	5	Apr. 20	9	43
Mar. 11	Mar. 19	8						do.			40
Mar. 10	Mar. 24	14	Apr. 3	10	Apr. 8	5	Apr. 14	6	Apr. 25	11	46
Mar. 12	Mar. 26	14	Apr. 7	12	Apr. 16	9			Apr. 27		45
Mar. 8	Mar. 22	14	Apr. 2	11	Apr. 7	5	Apr. 17	10	Apr. 28	11	51
Mar. 10	Mar. 25	15	Apr. 6	12	Apr. 11	5	Apr. 20	9	Apr. 30	10	51
Mar. 20	Mar. 21	1	Apr. 1	11	Apr. 6	5	Apr. 14	8	do.		16
Mar. 6	Mar. 19	13	Apr. 3	15	Apr. 13	10	Apr. 17	4	May 2	15	57
Mar. 12	Mar. 27	15	Apr. 8	12	do.	5	Apr. 20	7	May 5	15	54
Mar. 7	Mar. 19	12	Apr. 1	13	Apr. 7	6	do.	13	May 6	16	60
Mar. 20	Apr. 6	17	Apr. 13	7	Apr. 16	3	Apr. 23	7	May 7	14	48
Mar. 8	Mar. 27	19	Apr. 6	10	Apr. 13	7	Apr. 20	7	do.		17
Mar. 20	Apr. 4	15	Apr. 11	7	Apr. 16	5	Apr. 21	5	May 8	17	49
Do....	Apr. 6	17	Apr. 13	7	Apr. 17	4	Apr. 28	11	May 9	11	50
Mar. 21	Apr. 2	12	Apr. 8	6	Apr. 13	5	Apr. 20	7	do.		19
Mar. 20	Apr. 4	15	do....	4	do.	5	Apr. 29	16	May 11	12	52
Mar. 18	Mar. 30	12	Apr. 6	7	Apr. 11	5		do.			54
Mar. 10			Apr. 4		do.	7	Apr. 20	9	May 12	22	63
Mar. 20	Apr. 2	13	Apr. 6	4	Apr. 14	8	Apr. 24	10	May 15	21	56
Average ¹		13.2		9.5		6.4		8.2		13.8	50.1

¹ Total of averages of instars, 51.1 days.

TABLE IV.—Length of nymphal stage of the sharp-headed grain leafhopper, Tempe, Ariz., 1914—Continued.

SECOND GENERATION, MAY AND JUNE, 1914.

Nymph emerged from egg.	Date of first molt.	Length of first instar.	Date of second molt.	Length of second instar.	Date of third molt.	Length of third instar.	Date of fourth molt.	Length of fourth instar.	Date of fifth molt.	Length of fifth instar.	Total length of nymphal stage.
		Days.		Days.		Days.		Days.		Days.	Days.
May 15	May 21	6	May 26	5	May 31	5	June 7	6			
May 14	May 22	8	May 28	6	June 2	5	June 6	4			
May 18	May 25	7	do.	3	May 29	1	June 4	6			
May 16	May 22	5	May 23	2	May 28	5	June 1	4	June 7	6	22
May 15	May 21	6	May 26	5	May 29	3	June 2	4	June 8	6	22
May 14	May 18	4	May 25	7	June 1	7					
May 15	May 21	6	May 26	5	May 28	2					
Average ¹		6		4.7		4		4.8		6	22

THIRD GENERATION, JUNE AND JULY, 1914.

June 28	July 1	3	July 6	5	July 11	5	July 14	3	July 21	7	23
Do....	July 2	4	July 5	3	July 13	8	July 18	5	July 23	5	25
Do....	July 1	3	July 6	5	July 12	6	July 17	5	July 22	5	24
Do....	June 30	2	July 7	7	do....	5	July 15	3	July 26	5	22
Do....	July 1	3	July 4	3	July 8	4	July 13	5	July 19	6	21
Average ²		3		4.6		5.6		4.2		5.6	23

FOURTH GENERATION, AUGUST, 1914.

Aug. 1	Aug. 4	3	Aug. 9	5	Aug. 12	3	Aug. 16	4	Aug. 20	4	19
Do....	Aug. 5	4	Aug. 10	5	do....	2	Aug. 17	5	Aug. 21	4	20
Do....	Aug. 3	2	Aug. 8	5	Aug. 13	5	Aug. 18	5	do....	3	20
Do....	do....	2	Aug. 7	4	Aug. 11	4	Aug. 16	5	Aug. 22	6	21
Do....	Aug. 4	3	Aug. 9	5	Aug. 13	4	Aug. 19	6	do....	3	21
Do....	Aug. 5	4	Aug. 8	3	Aug. 12	4	Aug. 18	6	do....	4	21
Average ³		3		4.5		3.6		5.1		4	20.3

FIFTH GENERATION, SEPTEMBER, 1914.

Sept. 2 ⁴		Sept. 9 ⁵		Sept. 18 ⁶		Sept. 23 ⁷		26
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SIXTH GENERATION, OCTOBER AND NOVEMBER, 1914.

Oct. 8 ⁸	Oct. 11 ⁹		Oct. 17 ⁹		Oct. 23 ⁹		Oct. 30		Nov. 9		34
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¹ Total of averages of instars, 25.5 days.² Total of averages of instars, 23 days.³ Total of averages of instars, 20.2 days.⁴ About 20 nymphs.⁵ Nymphs in second and third instars.⁶ Nymphs in fourth instar.⁷ Sixteen adults.⁸ About 15 nymphs.⁹ About this date.

From Table IV it will be seen that it took the nymphs of the fourth generation the shortest time for development and growth, being an average of 20 days from egg to last molt. While the lengths may vary from season to season and from year to year, it is evident that during the summer months nymphs develop in about half the time of those of the first spring generation.

From the notes made by Mr. Wildermuth at Tempe, Ariz., in 1913, for the first spring generation the average length of the nymphal stage during March and April is shown to be 40 days, a few days less than that obtained the following year by the writer. (Table V.)

TABLE V.—*Length of nymphal stage of the sharp-headed grain leafhopper, Tempe, Ariz., 1913.*

Nymphs emerged from egg.	Adults emerged from last nymphal molt.	Length of nymphal stage.
		<i>Days.</i>
Mar. 18.....	Apr. 20.....	33
Mar. 24.....	May 5.....	42
Mar. 27.....	do.....	39
Mar. 24.....	May 10.....	47
Average.....		40. 25

HIBERNATION AND WINTERING.

Prof. Osborn¹ states that "hibernation seems to occur in all stages from the egg to the adult, although the great majority must pass the winter in the egg stage." At Tempe, Ariz., the writer searched diligently during January, 1914, for all stages of the species but found only adults. No eggs were deposited in cages either in or out of doors until February 4. Dissections of adult females during January showed them to be full of immature eggs. An experiment was carried on in which young nymphs were submitted to a temperature of 35° F. for 18 hours, at the end of which all nymphs were dead, showing that it is improbable that young nymphs could ever withstand the winter. Mr. F. H. Gates, another assistant of the Bureau of Entomology at Tempe, reports having taken adults on a number of days during November and December, 1914, and January, 1915. On December 15 he took several nymphs which were probably in the fourth or fifth instar. From his observations it would seem that the nymphs which had attained the fourth or fifth instar by late fall might survive the winter, although up to December 15 there had been no really cold weather at Tempe, the minimum temperature recorded to that date having been 28° F. At Charleston, Mo., during November and December no eggs or nymphs could be found, while the adults were present and active on warm days. It seems safe, therefore, to assume that the species winters over principally in the adult stage throughout the Southern States and in all probability the same holds true throughout the country.

GENERAL ACTIVITIES OF THE ADULTS.

The adults are exceedingly quick of movement, and might well be described as restless. They are easily disturbed or frightened and

jump at the slightest provocation. Because of this fact they are readily caught in the hopperdozer. A clump of tall grass was observed one day to be almost alive with adults, and although there was no wind and apparently nothing to disturb them, the adults suddenly hopped away, all at once. What caused the alarm was not determined. Adults, as well as nymphs, have the habit of dodging to the opposite side of a leaf or stem when approached by a foreign object. On days when there is a strong wind they remain in hiding close to the ground. They are most active during midday, and seldom may they be seen hopping about when dew is on the plants. As the sunlight recedes in the late afternoon they seek shelter under dried leaves and refuse, and at the base of the plant stems. While adults are most active on warm sunny days, during the intense heat of the summer they seek shade and damp places. From a series of observations it has been noted that they are more active on sunny than on cloudy days. Many adults, but not in such numbers as nymphs, can often be found feeding or resting on the same stem or leaf. They both rest and feed with head upward on the plant.

GENERAL ACTIVITIES OF THE NYMPHS.

Nymphs are even more active than adults, doing more running and dodging and less jumping about the plants. They seem to group themselves together; oftentimes 15 to 20 nymphs can be found on 1 square inch of leaf surface, and it is because of this that their feeding becomes injurious to the plant. Mr. Wildermuth has observed that the nymphs commence feeding immediately after hatching. The wind has a stronger effect upon the nymphs than upon the adults, and oftentimes a gust of wind will blow the nymphs several yards. They attempt to keep out of the wind by hiding but are rather easily blown from one plant to another, the throats of young corn plants making a favorite hiding place. When resting the first-instar nymph assumes a characteristic posture, carrying its abdomen slightly curled up and over. The nymphs are very sensitive to heat, and the direct rays of the sun for more than a minute or two on hot days will kill these young stages. Many times they have been observed to burst a bubble of excreta from the tip of their abdomen when disturbed or approached by a foreign object, and Mr. Wildermuth suggests that this may be a means of defense as it is in the case of nymphs of the three-cornered alfalfa hopper (*Stictocephala festina* Say).

OWIPPOSITION.

A few days after the male and female adults have emerged from the last nymphal molt copulation has been noted to take place. In 10 experiments carried on in confinement the male died within 1 and 2 days after copulation, although the females, in the same experi-

ment, lived for several weeks after oviposition. The females which overwinter copulate in the fall and may not oviposit until the following spring. The time between copulation and oviposition during other seasons is much shorter, generally about 10 days. As to the manner of oviposition Mr. Wildermuth noted the following: "Her ovipositor was already inserted when found, and she remained so for 22 minutes, being first observed at 1.55 p. m. and withdrawing the same at 2.17 p. m. The angle was changed several times, however, as she inserted the eggs, 7 in all, through the same slit which was about 1 mm. in length. Of course there is no way of knowing how long she had been in the position when found." Females do not necessarily choose protected parts of a plant for oviposition. In all cases noted with grains and grasses the egg pockets were constructed under the epidermis of the upper or inner side of the leaf. Mr. George G. Ainslie noted in Florida that egg pockets in corn are usually to be found in the midribs of leaves and frequently in stalks. In one instance he found an egg slit in a stalk just below the tassel. Eggs within the pocket are placed in a close-fitting row, with their long axes parallel. The number of eggs deposited by a female varies somewhat, but in general it may be said that a single female is capable of depositing between 40 and 50 eggs. The number to a pocket also varies from 2 to 12, with an average of 5, as shown in Table VI.

TABLE VI.—*Oviposition of the sharp-headed grain leafhopper in various plants.*

Plant.	Total number of egg pockets.	Total number of eggs.	Average number of eggs in a pocket. ¹
Wheat.....	22	102	4.6
Barley.....	16	85	5.3
Oats.....	26	155	6
Alfalfa.....	16	94	5.8
Johnson grass.....	2	12	6

¹ General average 5.5.

From 18 egg pockets in corn leaves Mr. Ainslie found that the number of eggs per pocket varied from 4 to 20, with an average of 12. This is probably due to the fact that the epidermal tissue of corn leaves is more flexible, thus allowing the construction of larger egg pockets. The period of oviposition may extend over from one to three weeks. Oftentimes a female will construct three or four pockets in one leaf. There seems to be no preference between the different grains for oviposition; however, grains and other broad-leaved grasses, such as Johnson grass, are preferred to alfalfa.

HATCHING OF THE EGGS.

The emerging nymphs burst the end of the eggshell irregularly and emerge head first. Eggs deposited in the leaves hatch sooner than those in stems, as there is not so much plant tissue covering them. Those in stems appear to be inserted more deeply into the plant. The nymphs issue at about the same time, irrespective of the position of the eggs in the pocket.

MOLTING OF THE NYMPHS.

The fourth molting of a nymph was minutely observed, the whole operation taking 20 minutes. The old skin split dorsally along the head and thorax. The head of the nymph first came out, slowly followed by the thorax and abdomen. The abdomen was pulled forward through the old abdominal skin and put through the thoracic slit. As the nymph gradually emerged it leaned or threw its weight backward until the tip of its abdomen was nearly out; then it shifted and spread its legs, taking a firm hold on the leaf surface. After completing the molt it remained still for several minutes.

In examining the last-molt nymphal skin an indication of sex was discovered. Outlines of the ovipositor or genitalia were quite prominent and plain on this cast skin. Attention was then directed to the examination of the last-instar nymphs, and it was found that there is a sex indication with all nymphs of the fifth instar, as the distinction between the male and female genitalia could readily be recognized. (See fig. 1, *i*, *j*.) No sex indications appear in the nymphs of the fourth instar.

ADAPTABILITY OF SPECIES TO CHANGE OF FOOD PLANT.

Only the nymphs of the last two instars can adapt themselves to a change of food plants to any extent. This fact offers a suggestion in the control of the species, in that cutting or grazing their food at the time the nymphs are young will tend to starve them, and thus many will be destroyed.

However, the adults find no difficulty at all in a change. If their food plants be destroyed or cut down, they immediately hunt for substitutes. Starving the adults in the fields would be next to impossible.

MIGRATION.

The species does not spread itself throughout one field or into other fields by the dissemination of the young nymphs, but almost wholly by the flight of the adults. The latter migrate freely from one field to another in search of attractive areas for food and oviposition. Besides this, Prof. Osborn remarks:¹ "The insect shows at times a distinct habit of migration at night." They have been reported

¹ Op. cit., p. 59.

around Columbia, Mo., "in such numbers that they could be gathered up by the bushel."¹ Strong winds in midsummer no doubt are responsible in many cases for what may seem a natural migration.

ENEMIES.

PARASITES.

Probably the most effective enemies of the sharp-headed grain leafhopper are its egg parasites, two species of which were reared in great numbers during the summer of 1914, while the writer was stationed at Tempe, Ariz. Both of these egg parasites were new to science, and Mr. J. C. Crawford² has described one as *Gonatocerus gibsoni*; the other Mr. A. A. Girault will describe as *Abbella auriscutellum*. Had it not been for these two egg parasites considerable damage would probably have been done by the jassid during the summer months. One of these parasites, *Gonatocerus gibsoni*, not only held the species in check but practically eradicated the pest in the Salt River Valley of Arizona. In this valley there was from 75 to 95 per cent of parasitism among the eggs of the second generation of the grain jassid between May 15 and June 15. Mr. J. H. Newton, a temporary assistant in the Bureau of Entomology at Tempe, found an 85 per cent parasitism from several hundred egg pockets examined.

Mr. George G. Ainslie, while in Florida during the spring of 1914, reared two species of egg parasites; one of these, reared in considerable numbers, has been determined by Mr. Gahan as *Brachistella acuminata* Ashm. Mr. Ainslie recorded a 79 per cent parasitism among eggs examined. Mr. R. A. Vickery reports having reared many parasites of *Ufens niger* Ashm., as determined by Girault. Five or six were reared from each egg.

There are many parasites which affect the Jassidæ and it is quite likely that this species comes in for its share. Although none has been recorded as having been reared from the grain leafhopper, yet in all probability some of the members of the families Proctotrypidæ and Dryinidæ materially help in suppressing its numbers. Several adults of *Athysanus exitiosus* Uhl. were taken which were parasitized by one of the Proctotrypidæ which appeared in the form of an external sacklike structure within which the parasite sucked the juices from the abdomen of the host. These adults of *A. exitiosus* were swept from fields where the grain jassid was very numerous. In the report of the Hawaiian entomologist and in the papers of Perkins and others may be found accounts of various parasites of the Jassidæ. The dipterous genus *Pipunculus* contains parasites of leafhoppers and according to Giard they are parasitic especially upon the family Jassidæ. The order Strepsiptera (the twisted-wing insects) contains

¹ Op. cit., p. 20.

² Crawford, J. C. Descriptions of new Hymenoptera, No. 9. In Proc. U. S. Nat. Mus., v. 48, pp. 577-586, sep. no. 2087, May 3, 1915. *Gonatocerus gibsoni*, new species, p. 586.

parasites upon jassids, but whether or not they have been reared from this species the writer does not know.

ENEMIES OTHER THAN PARASITES.

It is a common sight to see jassids caught in spider webs. Several adults and nymphs of *D. mollipes* have quite frequently been observed in webs, and in more than one instance the writer has seen spiders¹ carrying off dead adults. In Bulletin 108 of the Bureau of Entomology is an account of *Reduviolus fesus* L. as a predaceous enemy of leafhoppers. During the past summer the author observed on two occasions the large agricultural ant (*Pogonomyrmex barbatus* Smith) dragging off an adult grain jassid. Turkeys and toads have been observed catching and eating the adults in alfalfa fields. Prof. Osborn² gives a list of over 100 birds whose crops have been examined and found to contain jassids.

FUNGUS.

Prof. Osborn makes mention³ of a fungus, *Empusa grylli*, which causes an epidemic disease affecting this species. The occurrence of this fungus has been recorded also by Prof. F. M. Webster and Prof. H. Garman.

REMEDIAL MEASURES.

From a study of the habits of this jassid certain simple preventive measures present themselves. In the Salt River Valley of Arizona and in localities of similar conditions the keeping down of wild grasses, principally Johnson grass, along irrigation ditch banks, fence rows, and along roadsides during the summer months will do much in preventing the species from spreading and increasing in numbers. By cutting down or grazing sheep upon these broad-leaved grasses, which afford the preferred summer food, their summer breeding places will be destroyed and an immediate check upon the species produced.

As soon as possible after the grains are harvested the ground should be broken up and planted. If immediate planting is not practical, then the ground should be broken again by either replowing or harrowing after two or three weeks to keep down all native grasses and weeds.

Quoting from Osborn: "The direct treatment which has had the most thorough trial is the use of the hopperdozer, which consists of a sheet-iron strip coated with coal tar. The apparatus is drawn over the grass and the insects, hopping at its approach, fall upon the surface, and thus many are killed."⁴ The hopperdozer can be used to advantage while the grain is young and short. It should be used

¹ A list of spiders which feed upon leafhoppers may be found in Bulletin No. 108 of the Bureau of Entomology, U. S. Department of Agriculture, page 35.

² Op. cit., p. 28-31.

³ Op. cit., p. 57.

⁴ Op. cit., p. 37.

during the heat of the day when the leafhoppers are most active and jump at the least provocation.

Where the species is infesting pastures or grass lands close pasturing or cutting while it is in the egg stage is advised. Especially would this prove beneficial in the Northern States where the length of the egg stage covers several weeks. So far as the observations of the author go it would appear useless to burn grass for the destruction of the eggs, as when the leaves and stems wither or dry up the eggs do not hatch. Seemingly the eggs must have the moisture of at least the surrounding tissue for hatching. However, the burning of the grasses in which the species may be hibernating in the Northern States would no doubt destroy many of the adults.



BULLETIN No. 255

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER

July 22, 1915.

DOUGLAS FIR PITCH MOTH.¹

By JOSEF BRUNNER,

Entomological Assistant, Forest Insect Investigations.

NATURE AND CAUSE OF DAMAGE.

Pitch seams, gum check, windshake, or whatever these defects may be termed locally, have ever been recognized as a serious depreciating factor in the utilization of Douglas fir (*Pseudotsuga taxifolia*). These defects have heretofore been variously charged to windshake (mechanical strain), lightning, frost, blazes, fires, and various other unavoidable causes, but investigation of the trouble and its causes makes it evident that the work of the larvæ of the Douglas fir pitch moth (*Sesia novaroensis* Hy. Edw.) is the primary cause of a large percentage of these defects.

DISTRIBUTION AND EXTENT OF DAMAGE.

In the northern Rocky Mountain and Pacific coast regions it has been definitely determined that the Douglas fir pitch moth is responsible for at least 90 per cent of this damage.

A very similar larva,² found working in Douglas fir in the southern Rocky Mountain district, makes it quite certain that the same species is responsible for what similar depreciation in timber value may be existing there.

The loss occasioned by the work of this class of insects causes the difference in price between absolutely clear lumber and the lower grades or "dimension stuff." These insects work in the portion of the trunk which later clears itself of branches; hence only logs are affected which, were it not for previous infestation by them, would yield only the better grades of lumber.

Extensive correspondence with mill managers in various parts of the northern Rocky Mountains and Pacific coast range has elicited the fact that no accurate record is kept of the extent of the prevalence

¹ *Sesia novaroensis* Hy. Edw.; order Lepidoptera, family Sesiidae. Identification by Mr. August Busck.

² The insect from the southern Rocky Mountains, after the rearing of three specimens, proves to be *Sesia novaroensis*.

NOTE.—This bulletin is of interest to entomologists as a contribution to their specialty, and to owners and manufacturers as a business proposition.

of pitch seams in the logs used. But all Douglas fir sawyers estimated a general loss in the entire Douglas fir product of between 7.5 and 15 per cent due to this defect. The depreciation is lowest in the Rocky Mountain region and heaviest toward the coast, evidently corresponding to the respectively slower or quicker growth of the trees in the respective localities and to the relative scarcity or abundance of the moth in these regions.

The writer and his field assistants made a thorough investigation of the logs in the woods and during the sawing of them in the mill, from the manager of which the estimate of lowest loss was received. This mill cuts usually not less than 25,000,000 board feet annually, but the cut during the season 1913-14 was only 14,000,000 board feet. This investigation showed that from 15 to 25 per cent of all the logs in the 14,000,000 board feet had been damaged by the moth. Of the logs clean of branches, in which this sort of damage mainly prevails, fully two-thirds were depreciated in this manner, notwithstanding the fact that those from exposed localities, which are unfavorable to the insect, were practically free from the defect.

The results of the investigation were taken up with the mill manager and it was agreed that the loss in this case constituted but 5 per cent. Yet even this low percentage represented, at the selling price of the lumber at the mill, a loss for that season's low cut of \$18,900 to that firm alone. While this percentage is evidently much below the average, it is indicative of what this leak probably means to mills in the entire range of the Douglas fir.

MANUFACTURERS¹ BEAR THE LOSS.

At the present selling price the loss is almost entirely borne by the manufacturer. In the absence of the depreciation, consumers could get the best grades of lumber for the prices they now pay for the cheaper grades, and the manufacturers would besides be able to make a larger clear profit, as they would not have to handle the inferior material from the stump to the lumberyard. There is no help for the lumber now being cut, but the defect is avoidable in the future timber supply. There seems to be no reason, therefore, why the cause should not be eliminated and why mills and lumber consumers should be taxed forever by an insect the work of which involves such extensive financial waste.

SCOPE OF THE INVESTIGATION.

Evidently nothing was known in regard to the larval stages and activities of this insect until the spring of 1913, when, under assignment from Dr. A. D. Hopkins, the writer undertook a systematic study of

¹ By the term "manufacturer" is meant the "saw-mill" man, and by the term "consumer" is meant "contractor, buyer, and builder." A. D. H.

the seasonal history and habits of insects affecting the growth and development of trees, though a number of caterpillars, of what later proved to be this moth, had been caged during the autumn of 1912 for observation. Active cooperation in collecting larvæ and field notes with Messrs. Edmonston, Miller, Burke, Harvey, and all the entomological rangers assigned to the various western field stations from April, 1913, until late autumn, 1914, made it possible to determine not only the insect's distribution, but its comparative abundance and destructiveness in widely separated regions of the Douglas-fir range and also to make this investigation pretty thorough west from the eastern boundary of the State of Montana, toward the coast, and north of latitude $41^{\circ} 30'$ to the boundary of the United States.

LIFE HISTORY.

THE ADULT.

The Douglas-fir pitch moth, like all the members of the Sesiidæ, much resembles, in general appearance, certain wasps and flies. This resemblance is especially strong when the insect is in flight.

The ground color of the insect is black, with rich orange-red spots on the thorax and with all the segments, except the last, banded with the same color. Underneath the whole insect is rich orange-red. Aberrations in color are not frequent but exist, as the rearing of a wholly black female would indicate.

The forewings are transparent, opalescent, with black borders and prominent discal mark; the hind wings transparent, with slight discal mark and narrow black margin. The spread of wings is from 30 to 35 mm., about the size of an ordinary "yellow jacket." The male is about one-third smaller than the female and more slender.

THE EGG.

The eggs are brownish, slightly oblong, and are laid singly. A single female appears to produce slightly in excess of 30 eggs, the issue from two specimens being 34 and 37, respectively. In the field their incubation period is about two weeks.

THE LARVA.

With the exception of the head, which is dark brown, the larva (fig. 1) is white: through the transparent skin the darker intestines and their contents are plainly visible, thus making this larva readily distinguishable from that of *Vespa minima sequoia* Hy. Edw., which, to a slight extent, also infests Douglas fir, but which is more robust, has a denser skin, and is dirty white. Especially is this internal dark spot a feature in 1 and 2 year old larvæ, although it is retained to a marked

degree until pupation, which takes place in the third season after the deposition of the egg.

The head is small and rounded; the body cylindrical, rather slender in comparison with that of the larvæ of other sesiids. When full grown it is from 1 to $1\frac{1}{2}$ inches long.

THE PUPA.

The pupa is shining brown, armed with transverse rows of spines on the back of the abdominal segments, by aid of which it moves back and forth at will in the tunnel made by the larva before pupation in the covering pitch mass. When ready for the final transformation the pupa uses these spines for working its way through the thin layer of pitch at the mouth of the tunnel, by projecting its anterior segments to at least one-half of the entire pupal length through the opening, and holding itself securely during the escape of the moth.

SEASONAL HISTORY.

The pupal period as observed in the laboratory is 30 days, but under adverse weather conditions it seems to be prolonged a few days. Usually moths appear in greatest numbers the first sunny day after a rainy spell.

The general emergence of the Douglas fir pitch moth occurs during the month of June, although individuals emerge in Montana as early as May 15, and farther west adults may be found by the first of that month. On May 20 the writer noted the first female (no male was observed at large during two years of observation) flying up and down a Douglas fir tree, evidently in the endeavor to locate a favorable spot for oviposition. Fresh empty pupal shells were observed protruding from pitch tubes on infested trees as early as May 15. A living chrysalis was found early in April, which, allowing 30 days for pupation, would evidently result in adults appearing early in May. It is rather striking that most of the early chrysalids were found at the highest altitudes in which the moth is active. This makes it probable that the shortened seasons at high altitudes are frequently responsible for an extension of the larval period into the fourth year, just as, in consequence of late August oviposition at lower altitudes, a certain percentage of the insects do not attain maturity during the three years that this species requires for development from egg to adult. In such instances the larva pupates during the first warm days of the fourth season. Occasionally adults emerge up to the last of July and the first part of August.

The mature insect lives only about five days after emerging from the pupa, which accounts for its scarcity. Even where its work

proves that it is fairly numerous, it is only by good fortune that one gets a chance to observe its behavior. During two seasons of judiciously chosen days and locations for observations the writer saw but six specimens in the forest. They were all females, and each of them was apparently engaged in oviposition. While the insect swiftly wings its way up and down the tree trunk, the eggs are deposited, either at the edge of a wound or a perfectly smooth spot, oftener the latter, and only a single egg is deposited at each place.

In Montana, where the insect is not exceedingly numerous, the writer and Entomological Rangers Swartz, Wagner, and Fleming examined hundreds of trees, each of which displayed comparatively fresh, healed-over wounds, unquestionably of sesiid origin, but in no case was more than one larva of each of the triennial generations found at the same time in the same tree. This suggests that if there is an abundance of suitable trees for infestation a female, after depositing one egg only on a tree, leaves the latter, repeating the same operation until its supply of eggs is exhausted. Consequently quite a number of trees are thus affected by a single female.

From Ashland, Oreg., where the insect is much more abundant than in the Rocky Mountains, Mr. Edmonston reported as many as 6 larvæ, all of which proved to be of the same generation, from a single tree, and Mr. B. T. Harvey states that quite a number of trees in the coastal region are scarred from base to near the tops by the work of this moth.

I have no doubt that this apparent discrepancy in ovipositing is due solely to the fact that in regions where the insect is nearly ten times as numerous as in the Rocky Mountains several females by chance deposit eggs upon the same tree; in fact, they are compelled to do so, unless they are willing to oviposit on trees that are undesirable on account of growth.

By August 1 young larvæ from the June oviposition, upon close examination of the infested trees, may be readily located by the boring dust, which resembles that of *Dendroctonus pseudotsugae* Hopk. This dust is produced by the larva eating its way through the outer bark into the cambium. At the end of the first active season a pitch tube covers the wound as well as the larva which made it.



FIG. 1.—Three generations of larvæ of the Douglas fir pitch moth (*Sesia novae-rocensis*). Natural size. (Original.)

During the second season the larva merely maintains and enlarges the established chamber or tunnel, and, growing in size, as far as was possible to ascertain, molts the first time when 1 year old. The third season is passed like the second, the larva molting once again when two years old. By the end of this period the covering pitch tube is about the size of a silver dollar, depending somewhat on the shape of the wound inside.

The third spring after deposition of the eggs the larva, now nearly three years old, is ready to pupate. During the last two years the larva changes but little in size; the younger is somewhat more slender if of the same length as the older. The older larva, however, has become so thick skinned that it appears almost entirely white, while through the thinner skin of the younger generation the reddish intestines are still plainly visible. It is not a simple matter and requires a great deal of experience to separate these two generations.

With the exceptions noted for high altitudes and late oviposition, exactly three years after the egg was laid the adult appears, completing the life cycle and making the generation of the species triennial.

Although there are no seasons in which this insect is very abundant there are none in which it is unusually scarce.

HABITAT.

Unlike others of this group of insects, the Douglas fir pitch moth prefers the shade. It is most numerous in from 10 to 50 year-old Douglas-fir stands with a northerly exposure, and is consequently most injurious there. So-called "spruce swamps" are as much avoided as are the sun-exposed hillsides. While it may also be found to some extent on sunny slopes having a stand of trees sufficiently dense to provide practically constant shade, it is usually only trees which have been injured by some other cause which are here infested first. The insect is evidently attracted here from the preferred localities by the smell of pitch, just as barkbeetles are attracted by the smell of felled or fire-scorched timber.

It may be noted here that larvæ under pitch tubes which are much exposed to the sun are almost invariably killed during the winter months. Evidently the larva can not survive when kept active by the warmth of the sun while its sustenance is cut off by frost. This may probably explain why this insect is not numerous under conditions which expose it much to the influence of the sun. The pitch tubes of *Sesia novaroensis* and the bark of Douglas fir at the usual points of infestation do not provide the protection against the indicated influence as do, for example, the big pitch tubes and the bark of yellow pine for the larvæ of *Vespamima sequoia*, which survive under any exposure, presumably on account of this protection.

LOCATION OF AFFECTED AREAS.

The Douglas fir pitch moth has apparently a very marked habit concerning the preferred areas in given localities. An area in which it is depreciating the timber now may be readily located by simply watching the logs at the mill as they go through the saw and ascertaining where those with pitch seams come from. It may seem a matter of speculation to undertake to determine localities where the insect is numerous at present by thus examining trees which have been infested a century or more in the past, but it has been ascertained to be an absolutely reliable method. The success of this test not only proves that the sesiid is the cause of the depreciation, but it shows us in addition how we may determine the exact localities where the merchantable timber is liable to serious damage by the insect, because wherever the injury exists in the young, growing timber, which will be "loggable" a hundred years from now, it is practically certain that the mature trees had been afflicted in the same manner in their youth.

RANGE OF THE INSECT.

As already indicated, the range of this insect is over the northern Rocky Mountain and Pacific Coast regions and extends in all probability through the entire native range of the Douglas fir. From my own observations and numerous field notes and from larvæ collected in various parts between the northern boundary of the United States and latitude $41^{\circ} 30' N.$ and from the eastern boundary of the State of Montana to the western coast by other members of the Branch of Forest Insects and kindly put at the disposal of the writer, it is evident that the moth is most abundant in the western part of its range, a conclusion which in turn is verified by the losses estimated by millmen in the various sections of this area.

HOST TREES AND CHARACTER OF INJURY.

(Figs. 2-5.)

Douglas fir (*Pseudotsuga taxifolia*) is evidently the special host of this moth. However, although unable successfully to attack previously uninjured larch (*Larix occidentalis*) it breeds also and thrives well in blazes and other wounds on that tree, particularly in the pitch flow caused by a fungus, identified by Dr. James R. Weir, of the Bureau of Plant Industry, as *Trametes pini*. A great number of fungus-infested larch in a stand of timber may make this tree a real menace to the Douglas fir in the same area.

The healthier and quicker growing a Douglas fir may be, the more it appears to be subject to infestation by the moth. Trees are attacked when about 10 years old and after that until they are about

50 years old, when the bark has roughened and thickened to an extent to render it practically immune. However, on many trees the bark over previous sesiid wounds is frequently in a condition which invites reinfestation, and thus larvæ are often found in trees which are ready for logging. Especially is the latter a frequent occurrence, if, as a result of the circular pitch seam inside, caused by the moth many years ago, the tree is split by wind strain from that seam straight to the surface of the bark. Toward the end of the first-year work of the larvæ, usually about August, the effect of



FIG. 2.—Work of the Douglas fir pitch moth: Evolution of pitch blister and pitch seam. (Original.)

their presence is shown in the growth of the new layer of wood, which is restricted immediately above and below and to some extent on the sides of the wound. Pitch formation in this new layer of wood and in the underlying layers, in an attempt by the tree to protect itself, forms the nucleus of the pitch blister. The inflexibility of this blister, even if the timber is but normally swayed by the winds as the tree grows taller, is bound to cause a further parting of the tissues and ultimately results in the pitch seam, which so greatly depreciates the value of the logs as lumber material. The afflicted tree endeavors, during the three years required by the larva to develop to adult, to wall up the wound, and the larva tries to maintain its established position; this struggle results in the wound

becoming rather deeply embedded in the woody tissue. From then on it depends upon the growth of the tree whether only the pitch blister at the base of the wound is to be inclosed in the healthy tissues or whether the pitch from the pitch tube and bark also is to be inclosed. As a rule, a tree of slow growth heals from the inside and the injury is less apparent, whereas a tree of rapid growth puts forth such a quantity of new growth over the injured spot that clean healing is impossible and a serious defect is evident almost immediately,

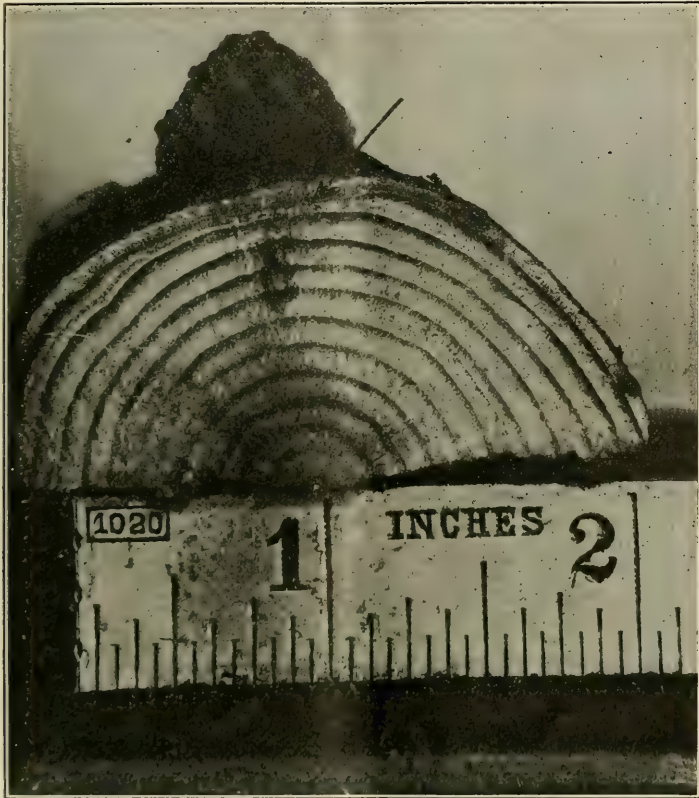


FIG. 3.—Work of the Douglas fir pitch moth: Effect of infestation on the wood growth 2 inches below (and above) the wound the first year after attack. (Original.)

even without the added aggravation of mechanical wind strain. The effect of mechanical strain during succeeding seasons upon trees afflicted with serious wounds from the very beginning renders them unfit as lumber material.

The real depreciation of the future saw log is inflicted while the trees are less than 50 years old, and most of the pitch seams, which result more or less in a separation of the inner and outer tissues, are caused by the insect when the trees are quite young. While the

original wounds made by individual specimens may be several feet apart on the trunk of a tree, as the latter grows taller and is swayed by the wind the inflexible blisters are gradually lengthened and widened and finally united. In trees which had been infested on all sides the seams are entirely circular, while in those infested on one

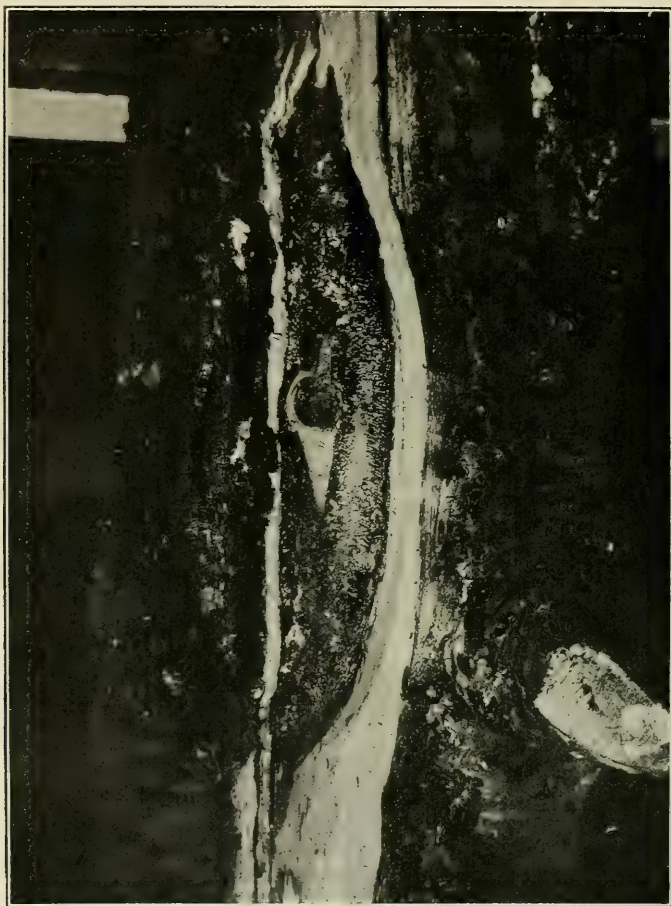


FIG. 4.—Work of the Douglas fir pitch moth: Pitch blister two years after emergence of moth, with tissues which had already grown over it perfectly, removed at one side. Natural size. (Original.)

side only, a frequent occurrence, the seam is semicircular. However, the cause which underlies both these effects is the same.

EVIDENCE THAT IT IS INSECT WORK.

(Figs. 6-8.)

Full-blown pitch seams probably never pass into lumber, and affected parts of logs are either converted into small "dimensions,"

laths, or firewood. Therefore to illustrate them adequately it would be necessary to split tree trunks, often for the length of several logs, to show a side view of an entire seam, and even if this were accomplished successfully the result would be merely something like a board which had been split and had been loosely stuck together again. With the exception of figure 2, showing the evolution of



FIG. 5.—Wound caused by the Douglas fir pitch moth. Photographed soon after emergence of moth. Natural size. (Original.)

the pitch seam, the photographs used to illustrate the injury to Douglas fir by pitch-moth infestation are from material from which the insect emerged so recently that the cause of the wounds is obvious. Such injury within the tissues of a coniferous tree is never eliminated in the course of years, but rather becomes accentuated when the split of the tissues is later extended for the length of many feet by mechanical strain.

WINDSHAKE AND LIGHTNING NOT THE CAUSE OF PITCH SEAMS.

The contention that windshake is capable of causing pitch seams in perfect tissues of this tree is not tenable when the facts at hand are considered. If this were true, freely exposed trees should contain the greater number of pitch seams, and those in sheltered positions should have few or none, which is not the case. Also, Douglas

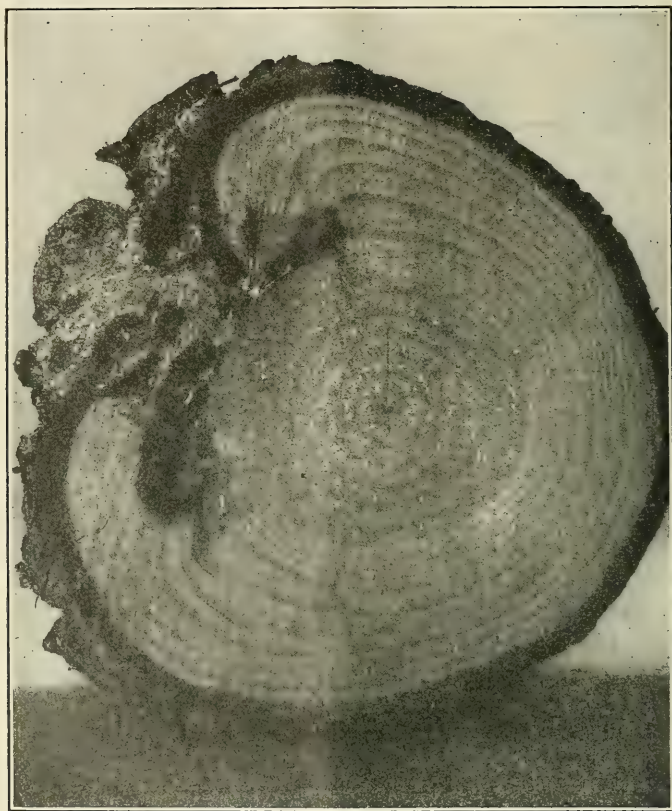


FIG. 6.—A cross-cut showing wound caused in a young tree by the larvæ of the Douglas fir pitch moth. Reduced. (Original.)

fir is generally recognized to be of more tenacious fiber than larch, as is frequently illustrated in timber-sale contracts, which provide for the "butting" of the latter trees over a certain size, on account of depreciation in that part of the tree by "genuine windshake." To the knowledge of the author timber-sale contracts contain no such clause or even a similar clause concerning Douglas fir. While in the larch, recognized to be subject to windshake, owing to brittleness, the damage by windshake extends but a few feet above the base, in the admittedly tougher Douglas fir the damage from supposed "windshake" frequently runs up to 60 and more feet. "Wind-

shake" in larch above a few feet from the ground is practically nonexistent, since this tree, more than any of our conifers, is, if healthy, immune to insect attack, except to the foliage, and, if attacked, is more able to repulse the onslaught from the outset.

"Lightning" has been included in the same category with "wind-shake" as a cause of pitch seams in Douglas fir. The theory that lightning is a causative agent refutes itself by mere examination of the damaged material. It is the lower two-thirds of the tree trunks which are seriously pitch seamed, while the upper part is almost invariably free from the defect, and it is not reasonable to assume



FIG. 7.—Development of a "pitch seam" only four years after the emergence of the Douglas fir pitch moth. Note the enormous growth the tree put forth to cover the wound. Greatly reduced. (Original.)

that the electric spark would persistently leave the tops untouched and so frequently injure only the part below the branches.

Another point in this regard is the fact that judging from the location of the seams in the trunks the trees could not have been of very great size when the defect occurred. A casual stroll in the woods will convince the most heedless observer that it is not the younger trees which are most subject to lightning.

It is evident from the foregoing that infestation of a tree by the Douglas fir pitch moth does not result in immediate financial loss.

This has to be borne by future generations, just as the present is paying for the damage inflicted by the insect a century or more in the past.

Actual tally of sesiid wounds, blazes, bullet wounds, bruises by blasting, etc., all of which cause blister effects in wood tissue, was



FIG. 8.—An embryo pitch seam caused by the Douglas fir pitch moth only a few years after emergence of moth: A, Pitch blister which the larvæ caused before emerging; B, a break in the tissues by wind strain on account of the defect; C, break filling with pitch; D, inclosed pitch from pitch tube which caused imperfect healing; E, parts of pitch tube which covered the larvæ, still part of the surface covering. Reduced. (Original.)

made in a stand of Douglas fir about 30 years old, where conditions were most favorable for the operation of all the latter causes. This tally demonstrated that in this area of about 30 acres the sesiid wounds averaged, up to 15 feet from the ground, a little over 96 per cent, while the wounds from all other causes combined represented less than 4 per cent. Wounds above 15 feet could safely be consid-

ered almost entirely due to moths, but they were not counted. If they had been counted the percentage of all other factors would not have exceeded 1 per cent, and this in a location more or less unfavorable for the moth.

CHARACTER OF LARVAL WORK.

(Figs. 9-10.)

If trees have been injured the eggs are evidently deposited by the moth at the edge of wounds, regardless of their origin, and the larva

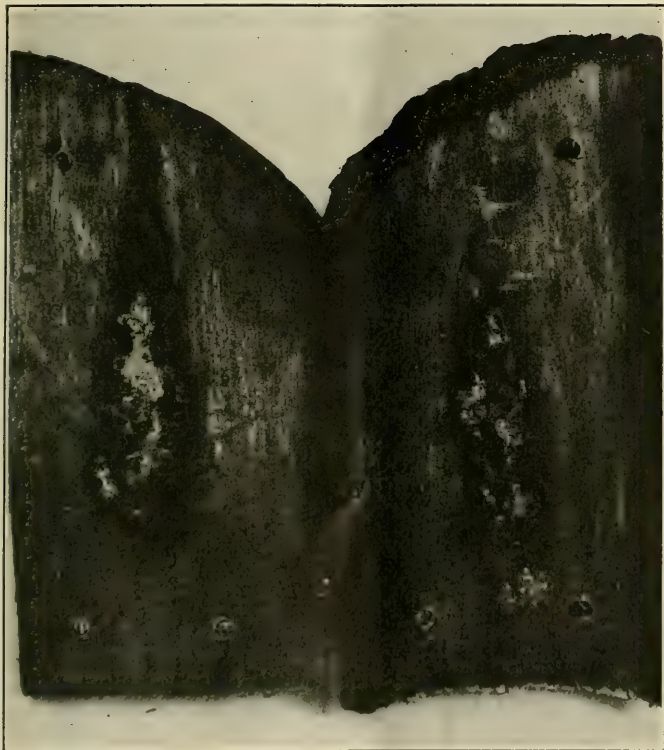


FIG. 9.—Tunnel at the end of the first active season of the larvæ of the Douglas fir pitch moth. Natural size. (Original.)

begins feeding at such places. The larva apparently follows the line of least resistance, because the resulting tunnel is likely to assume any shape in such cases. On perfectly sound trees the egg is evidently deposited where the bark is absolutely smooth and fresh, and the larva feeds upon the bark as soon as it slips out of the eggshell. This is apparently also the reason why trees with thick bark are attacked only where sesiid or other partially healed wounds provide conditions which answer the same requirement.

After the young larva has penetrated to the cambium, which usually occurs about August, or at a time when the growing period of the tree for the season is ended, it excavates a tortuous tunnel from 1 to 2 inches in length, parallel with and transverse to the grain of the wood. The length of the tunnel at completion depends largely upon the growth of the infested tree. In slow-growing trees



FIG. 10.—Pitch tube covering larvæ of the Douglas fir pitch moth the second year after infestation. Natural size. (Original.)

it reaches occasionally a length of from 5 to 6 inches at the time of moth emergence, while in very vigorous growers the larva maintains its well-being within a circular-shaped pit, not more than 2 inches in width, deeply embedded in the woody tissues of the cambium.

The surface of the wound is invariably covered by a pitch tube of the color of the bark. When the outer crust of the tube is removed it is found to contain pitch and the excreta of the larva. If the same wound is reinfested, soft pitch mixed with the old crusty pitch

usually indicates the presence of the larva. Plural infestation under one pitch tube has not as yet been observed.

It is only upon very close examination of the tree that the infestation will be revealed, so perfect is the blending of color of the Douglas-fir pitch and the bark, notwithstanding the fact that the covering pitch tubes are about 2 inches in diameter and protrude at least 1 inch from the surface of the bark. The protuberances so much resemble a knobby growth that considerable experience is necessary to enable one to distinguish them at sight.

The attack is restricted to the main trunks of trees, the first, second, third, and fourth logs being usually most affected, the injury becoming notably absent above 60 feet from the ground.

Trees are never killed outright, although very vigorous trees, if attacked several seasons in succession, become so weakened that their originally less robust neighbors easily outgrow them.

RELATION TO OTHER DESTRUCTIVE INSECTS.

In most localities where the Douglas fir pitch moth is present Douglas fir and larch trees are to be found with dead bark on the trunks in strips several inches wide and often more than 20 feet long. This peculiar injury, except in the case of *Tetropium* in larch, is usually attributable primarily to fires, bruises by falling trees, and perhaps, to some extent, lightning. Examination of these strips under the bark usually reveals sesiid larvæ, or at least abundant traces of their work. The galleries under the bark contain, in addition, the unmistakable evidence of beetle infestation. In all such cases coming under the writer's observation these beetles of the genera *Melanophila* or *Tetropium* were found to have infested the trees primarily or after they had sustained the mechanical injuries before mentioned, and to have been the agents which prepared favorable propagating places for the moth. Extended observations lead the writer to believe that these and similar beetles do not follow the moth, but that the moths occasionally adopt the galleries, etc., of the beetles.

A few trees which had been outstripped by their companions, evidently on account of previous moth infestation, were noted as subsequently killed by *Scolytus unispinosus*, but, considering that these trees when killed by the beetles were already worthless as timber producers, the interrelation of moth and beetle in this instance seems of no economic consequence.

*Tespamima sequoia*¹ is another very injurious pitch moth which infests Douglas fir in old wounds and branches, and especially wounds

¹Brunner, Josef, The Sequoia pitch moth. U. S. Dept. Agr., Bul. 111, 11 p., 5 fig., July 11, 1914.

originally made by *Sesia novaroensis*, thus extending the injury. In Montana it infests wounds in the trunks of Douglas fir to the extent of about 1 per cent. But in the vicinity of Ashland, Oreg., *Vespa-mima* appears to have developed a special liking for this tree. Fully 10 per cent of the pitch-moth larvæ sent me by Messrs. Edmonston and Miller from Ashland proved to be *Vespa-mima sequoia*. According to the accompanying notes, all of the larvæ of this species were collected in wounds previously made. At Placerville, Cal., a single larva of *Vespa-mima* was collected in Douglas fir, and this was in an old wound.

Wounds in Douglas fir, especially those made by the pitch moth, presumably on account of their better protective character, are usually infested for several seasons by the larvæ of a small moth of the genus *Laspeyresia*.¹ Two or three larvæ are frequently found around the edges of a single wound. The *Laspeyresia* also attacks young Douglas fir at the base of branches independently, and, although the attack itself usually does no permanent injury, the resulting accessibility to the cambium often induces infestation by the *Sesia*. That the work of *Sesia* is responsible for the increasing numbers of *Laspeyresia*, by providing favorable conditions for propagation, seems a reasonable conclusion, yet it is doubtful if the abundance or scarcity of *Laspeyresia* similarly affects the pitch moth, which is well able to establish and sustain itself.

RELATION TO NATURAL ENEMIES.

In localities where *Sesia novaroensis* is more than commonly numerous nearly 20 per cent of its larvæ are killed before reaching maturity by a tachinid parasite.² The influence of this parasite as a check on the numbers of *Sesia* or as lessening the depreciation of timber appears from a strictly economic standpoint to be practically nothing, since it appears from extensive observations that only those moth larvæ under imperfect pitch tubes are subject to attack by the parasite. As the greater number of pitch tubes form an impenetrable barrier against the parasite, there is little reason to expect that it will ever be a factor in the control of the pitch moth.

MEANS OF CONTROL.

In determining control measures for use against the Douglas fir pitch moth five readily accessible areas were selected for detailed investigations. On all of these the stand of timber was mixed and the conditions were those which obtain in almost any location west of the Rocky Mountains, excepting the pure pine stands. The results

¹ Identification by August Busck, Bureau of Entomology.

² Identification by C. T. Greene, Bureau of Entomology.

of the investigations and experiments (Table I) made it evident that to accomplish any permanent good under general forest conditions it is best to extend control over large areas. In Project III, for example, where the infestation is in general rather slight, collecting was done within a 5-section limit over 460 acres only, in strips containing a stand of trees of a character more susceptible to attack, and while the destruction of the larvæ resulted in some reduction of the annual infestation, it could not in any sense be regarded as an important factor in reducing the ultimate depreciation of the timber without the application of constant attention.

TABLE I.—*Control of the Douglas fir pitch moth: Projects and results.*

Project No.	Damage.	Sections.	Acres.	Larvæ collected.		Remarks.
				1913	1914	
I	Medium....	5	3,200	790	74	To June; from August to December, 8 larvæ found in area. Collected thoroughly. Thorough search. From 1913 oviposition. From 1914 oviposition. Collected during December. Collecting done in strips of reproduction within the mature stand. From 1913 oviposition. From 1912 oviposition.
II	Serious.....		30	101	5	
III	Slight.....	5	460	94	53	
					16	
IV	Heavy.....		40	207	9	
V	Serious.....		10	41	2	

Project No.	Age of stand.	Local conditions.
	<i>Years.</i>	
I	10-40.....	Surrounded by older stand; hills and flats alternating. Northern exposure; practically isolated, except for adjoining stand of mature timber.
II	30.....	
III	120, with strips of reproduction from 10 to 40 years old.	Heavy mountain forest in a solid stand which extends for miles.
IV	40.....	Creek bottom; flat surrounded by steep hills stocked with 10-year-old and younger reproduction.
V	15-20.....	Practically isolated, being surrounded by yellow-pine stand free of any seed.

In Project I, which also covers five sections, the larvæ were destroyed throughout, and during the autumn of 1914 but 8 larvæ were found near the border of the area. In Project I a daily inspection at the proper period in the year along the border would be amply sufficient to protect the entire area from a serious infestation until such time as the trees shall have outgrown the danger stage.

The principle of "isolating" stands susceptible to infestation should be the potent factor in control of this insect. Let us take a practical example of what is meant by isolation in this regard. Two streams, distant from each other in an air line say a couple of miles, run parallel from their source at the base of a mountain to the open farm lands, but between them is, as usual, a dividing ridge. Along both streams, in favorable locations, the moth is equally numerous, yet elimination of the moth along the entire length of one stream

means the practical dissociation of it from its neighbor, because the dividing watershed line invariably provides unfavorable conditions for moth existence on one slope. (See *Habitat*, p. 6.) No matter in which direction a stream may flow, one slope of the watershed is always subject to a greater degree of sunlight than is favorable to this insect. Again, a sufficiently wide strip of trees other than Douglas fir on the opposite side of a stream may safely be regarded as a buffer, as was indicated in the results of investigations in Projects II, IV, and V. Project V was an almost pure stand of Douglas fir which was connected with the next nearest solid block of Douglas fir, about 1 mile distant, by a few stragglers of this fir through the solid stand of surrounding yellow pine.

Small tracts, which can be given attention for a few days annually, may be kept comparatively free of infestation and, even if infested, the removal of the larva during the first year of its life will prevent the development of the wound to the serious stage. Of course the infestation, even for only a year or less, will leave a pitch spot in the tissue, just as is produced in case of unsuccessful *Dendroctonus* beetle attack or the infestation by bark maggots, but the result will not be nearly as serious as when the larva is left in the tissue to complete its life cycle. From the investigation it also developed that one experienced man could practically clean and keep clean an area 50 miles square or, roughly, 1,600,000 acres of this class of damage within a few years. The long period of three years that is required for the insect to develop from egg to adult is a decidedly strong factor in the case of its control. Considering the amount of annually "loggable" Douglas fir from such an area under the mixed-stand conditions that ordinarily obtain, and the percentage of depreciation wrought by the insect, the employment of such caretakers would appear to be a good investment, even if there were no other insect problems requiring the attention of the men.

If in the future lumbering interests are not to pay the same tax to the pitch moth of our time as is now contributed, due to the depreciation of timber a century and more ago, the present day is the time to aid in the elimination of this pitch moth.

As is apparent from the foregoing text relating to the larva and to the seasonal history of the moth, two generations of larvæ, excluding the overlapping percentage at high altitudes and from late oviposition, may be found at any time of the year. For example, by July 1, 1915, the issue from the 1912 oviposition will have emerged and between that date and September 1, when the pitch tubes produced by the issue of the 1915 oviposition are sufficiently developed to be readily seen, only larvæ from the 1913 and 1914 issue are to be found. From September 1 until June 1, 1916, when the 1913 issue

will emerge, 3 generations, those of the issues of 1913, 1914, and 1915, may be located and destroyed at one time. However, no matter how close the examination, a few infested pitch tubes will always escape notice. It is therefore advisable that the same area be scouted several times in the course of each season. After an area is once cleared it should not be a difficult task to keep the insect in check and much the less so if control projects cover big sections.¹

Destruction of the larva is the only remedy that can be used to reduce an infestation. When the infested pitch tube is located, it should be separated from the tree, the thus exposed larva killed, and to insure cleaner healing the ragged edges of the wound should be smoothed with a knife or small ax, after which they should be painted with creosote or a similar preparation, to prevent reinfestation by insects or fungi. The enlarging of the wound by the smoothing of its edges will also leave a pitch blister in the tissues, but the ultimate result will not be nearly as disastrous as from the untreated sesiid wound, since a clean healing from the inside obviates much of the chance of its producing a circular seam. Freshly vacated wounds might be treated the same way with profit.

SUMMARY AND CONCLUSIONS.

That the financial loss caused by *Sesia novaroensis* in Douglas fir product is great and represents a greater leak in profits to manufacturers than any other avoidable item is evident.

That the depreciation for which this age is taxed can be eliminated for the benefit of posterity at an expense so low that it is but a fraction of that which the damage represents seems to be sufficiently demonstrated by the results of the investigations and experiments.

The manufacturer will always bear the greater extent of the loss, and the manufacturing interests should inaugurate the elimination of the insect by putting into effect a policy of paying better prices for timber where it is clear of pitch seams and reducing the price commensurately for material where logs are defective to an appreciable extent, instead of paying a uniform amount of so much per thousand feet in a locality, without consideration of existing conditions. This would create among owners of forest lands a stimulus to produce clear timber, free of pitch seams, by a little attention annually, and even if the immediate desire should be merely the obliteration of the evidence on young trees by which the defect in the merchantable material is determined, for the purpose of deceiving the lumber cruisers, it would nevertheless produce the desired end.

¹ Under "Habitat" and "Host Trees and Character of Injury" is suggested where to look for infested trees.

On account of the long life cycle of the Douglas fir pitch moth its elimination, in any country where forestry is sufficiently advanced to be a profitable business and where the forests are taken care of as they should be in order that they may be profitable, will follow. In the range of the Douglas fir there are millions of acres of forest land which are inaccessible and practically worthless at the present day, but they will remain so not much longer, and with advanced methods in forestry *Sesia novaeboeae* is bound to disappear ultimately. The process of its eradication will necessarily be slow, but this is no reason why a systematic policy to attain this result should not now be adopted in areas which have been and are being logged and which, it is certain, will be logged again when the reproduction attains merchantable size.

While in this paper only the more serious result of pitch-moth infestation during the first 40 years' growth of trees is considered, it does not mean that the insect does no damage in older and mature trees. As is seen under "Host trees," it infests these also under favorable conditions, but in such cases the infestation results only in the so-called "gum spots," the pitch blisters being too near the surface of the trees to cause serious breaks and ultimate "pitch seams" by mechanical strain in the part of the tissues rendered inflexible. In regard to the "gum spots" in Douglas fir, which entail practically no loss to mills, but for which the builder and consumer foots the bill entirely, the pitch moth is responsible for not more than 10 per cent, *Dendroctonus pseudotsugae* for not less than 70 per cent, and all other causes for about 20 per cent of the damage.

SYNONYMY.

Aegeria novaroensis Henry Edwards, Papilio, v. 1, 1881, p. 199; Grote, New Check List N. Amer. Moths, 1882, p. 12; Beutenmüller, Bull. Amer. Mus. Nat. Hist., v. 4, 1892, p. 172.

Sesia novaroensis Smith, List Lepid. N. Amer., 1891, p. 20; Beutenmüller, Bull. Amer. Mus. Nat. Hist., v. 8, 1896, p. 133; Beutenmüller, Memoirs Amer. Mus. Nat. Hist., Monograph of the Sesiidæ of North America, 1902, p. 289.

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L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER

July 27, 1915.

KATYDIDS INJURIOUS TO ORANGES IN CALIFORNIA.

By J. R. HORTON and C. E. PEMBERTON,

Scientific Assistants, Tropical and Subtropical Fruit Insect Investigations.

INTRODUCTION.

There are at the present time in the San Joaquin Valley of California over 43,000 acres of land devoted exclusively to the cultivation of citrus. The citrus strip lies along the Sierra foothills between Bakersfield and Fresno. Although some citrus trees have been grown in this area for more than 25 years, most of this great acreage has been planted in the last 15 years. The transformation of this strip of land from a semiarid grain-growing belt into an irrigated fruit-growing area has so changed the status of certain formerly obscure species of insects native to the locality as now to bring them into prominence as pests.

One of the more important of these species is the fork-tailed katydid, *Scudderia furcata* Brunner. The amount of damage done by this insect has increased considerably since 1910, when it first came to the attention of the senior author. In 1912 it caused a loss in several orchards of a full fourth of the crop.

Associated with the fork-tailed katydid in the orange groves and closely resembling it is the angular-winged katydid, *Microcentrum rhombifolium* (Sauss.). This insect is also responsible for a certain amount of injury to orange trees annually, feeding voraciously, as it does, upon the leaves. It is, however, of much less importance than the former, and is treated here rather because of close association with and resemblance to the fork-tailed katydid than on account of its economic importance. No distinction has heretofore been made between these two species in the orange groves of California.

THE FORK-TAILED KATYDID.

NATURE AND EXTENT OF INJURY.

The fork-tailed katydid (*Scudderia furcata* Brunner), so named from the peculiar forked appendage at the tip of the abdomen in the male,

Note. Technical description of two katydids causing serious damage to oranges in California are contained in this bulletin. Remedies and methods of control are discussed.

is so large that a day's feeding by a single individual may mean the destruction of several small oranges. Once an orange is attacked it is invariably rendered unfit for sale, and therefore usually left on the ground in the field at picking time.

The young katydids are on the trees and actively feeding at about the time the latter are beginning to lose their petals, and the injury usually begins at this stage. The insect will sometimes attack the blossom buds, generally gnawing a hole through the petals to reach the pistil and ovary, these organs often being destroyed in a considerable number of blossoms (figs. 1, 2). The petals themselves have apparently but little attraction for the insect.



FIG. 1.—Orange bud injured by katydids. (Original.)

Whenever as many as 15 or 20 of the nymphs are found on a tree, the injury to the immature fruits becomes quite noticeable and a quantity badly chewed will be found on the ground (Pl. I, fig. 1). The injured oranges usually have been more than one-third destroyed or have received one or more holes large enough to

admit the head and thorax of the slender katydid nymphs, such holes often extending entirely through the oranges. Many other oranges which have been two-thirds or more eaten away will be indicated by the portions remaining on the trees. The oranges which have been only slightly chewed when small and those which receive the injury after they are considerably grown and have "set" firmly to the tree remain to ripen only to be "culled" out either at picking time or in the packing-house. At picking time many of these damaged fruits are conspicuous owing to the clean-cut circular holes in the rind, which vary from the size of a dime to about that of a silver dollar (Pl. I, fig. 2; Pl. II, fig. 1). The insects have the habit, however, of chewing into the larger fruits from the side toward the tree trunk, seeking the shade and also protection from birds, and the injury may not then be noted until the fruit is picked. The holes in the more mature fruits, as in the very young ones, are often deep, extending through the rind and rag, well into the pulp. Many oranges are split wide open as the result of katydid injury inflicted when they were only about one-fourth matured, due to inability to expand along the dried edges to accommodate growth (Pl. II, fig. 2). All oranges which have been attacked after the crop has thoroughly set mature with the sound fruit, on the trees, and although edible they must be considered a dead loss, since they are unfit for shipment.



FIG. 2.—Young Navel orange from which the pistil remains and part of the fruit has been eaten by katydids. (Original.)

Examination in the orchards of hundreds of boxes of oranges throughout the San Joaquin Valley during the picking seasons of

1911 and 1912 showed the injury to be very widespread. Very few orchards were examined which failed to indicate the presence of this katydid by the unsightly chewed fruit, either in the boxes or discarded as worthless upon the ground about the trees (Pl. II, fig. 2).

In 1912, before the picking season commenced, an examination was made of all the fruit on 10 or more trees in each of 53 orchards of Washington navel oranges scattered throughout the orange district to determine the total injury to the mature fruit. Only 3 of these orchards were entirely free from katydid-injured fruit. In 3 of the remaining orchards the damage, though present, amounted to less than 1 per cent. In the remaining 47 orchards from 1 per cent to 39 per cent of the maturing crop was rendered totally unfit for sale by the katydids. Fourteen of the 47 orchards suffered a loss of 10 per cent or more of the crop. The total loss of fruit from this cause for the 47 orchards averaged 8.2 per cent of the entire maturing crop. These estimates do not, of course, include the very young fruits which are completely destroyed soon after the petals are off, and this loss is rarely noted at all by orange growers.

The orchards in which the injury is excessive are not necessarily in isolated locations, as has been supposed, nor are they growing under any unusual conditions. The katydid, however, appears to be slightly more abundant in the foothills regions, and it shows some preference for young and vigorously growing orchards.

Several groves which had previously suffered but slightly from katydids were called to the attention of the writers in 1911 and 1912 because of the increasing injury. Thus an orange grower informed the writers that he had seen the familiar circular holes cut in the fruit by katydids on his place for 14 years. Such a small percentage of fruit was affected, however, that he had paid no special attention to it until the fall of 1911, when he noted a material increase in injury. Just after the crop was picked in 1912 a visit was made to his orchard and the injury found much worse than in 1911. The pickers had just finished a 6-acre plat of young navel trees, from which they had discarded 12,000 oranges because of katydid injury. About 100 boxes of oranges were therefore ruined in this 6-acre block of trees, and as 800 boxes of good oranges were picked from these trees a complete loss of 11 per cent of the mature crop plus an undetermined percentage of young fruits and blossoms which might have become fruit was sustained. A 15-acre orchard of young Washington navel trees, which were but slightly infested in 1911, became seriously infested in 1912. When the final picking was made, 533 boxes of good oranges were secured from the orchard, while approximately 175 boxes, 21,000 oranges by count, were rejected as worthless because of splits, gashes, and holes caused by katydids.

The most striking example of injury by this katydid that has come to the attention of the writers was that of a navel-orange grove so

grossly infested in 1911 that 57 per cent of all the mature fruit was ruined. This was determined by actual count made at picking time. Many undeveloped, badly chewed oranges on the trees and the usual dried remains of other riddled fruits on the ground were not taken into account in this examination. These trees, which should have produced, at the very least, 2 boxes of oranges each, averaged only about 7 sound oranges per tree. In 1912 the injury was again very great in this orchard. A large amount of fruit was chewed and destroyed while still small, and the average number of oranges was but 9 per tree after all dropping had ceased and the fruit had matured.

It should be mentioned that, to the present time, the most severely damaged orchards are generally those in which the trees are 10 years of age or younger, although several of the older orchards suffered greater injury in 1912 than in any previous season.

Injury to Valencia oranges.—Examination of all the fruit on several trees in each of 15 Valencia orange groves showed this variety quite as susceptible to attack by katydids as the various navel types, the percentage of injury being practically the same in both.

Injury to foliage (Pl. III, fig. 1).—The fork-tailed katydid, as well as the angular-winged katydid, feeds during its entire life upon the leaves and stems of orange trees. It selects by preference the new, tender growth, filling the leaves with holes and often completely destroying the stems. The injury to foliage has not been serious except on trees where the nymphs were unusually numerous.

FOOD PLANTS.

Under the conditions prevailing in the San Joaquin Valley citrus area, the fork-tailed katydid feeds almost exclusively upon the sweet oranges, where at all times the food supply is abundant and attractive. It has not been taken upon any other variety of citrus. Weeds are rarely allowed to grow in the orchards and, except in early spring, do not flourish on the unirrigated lands surrounding them. The insect has not in a single instance been found upon native weeds.

On one occasion, in October, 1911, the senior author heard a male of *Scudderia furcata* stridulating in a patch of string beans. Examination of the plants disclosed two adult females, and a bean leaf was found which contained two eggs. The following month he found eggs of the species in the leaves of apple and peach trees growing near orange trees. The insect was reported to the writers by an orchardist as injuring grapevines on his place. This report was verified and the injury found upon both leaves and berries.

Other writers have reported the insect as occurring upon "weeds," "coarse grasses," "thickets," "hedges," etc. Its food plants undoubtedly comprise widely different species in various sections of the United States. Under the name *Scudderia curvicauda* (De Geer) it

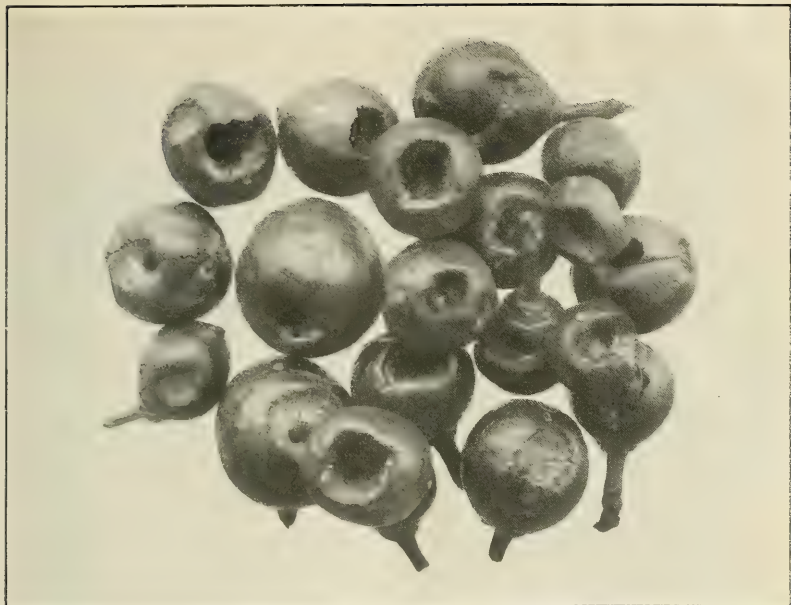


FIG. 1.—YOUNG NAVEL ORANGES RIDDLED WITH HOLES BY KATYDIDS. (ORIGINAL.)

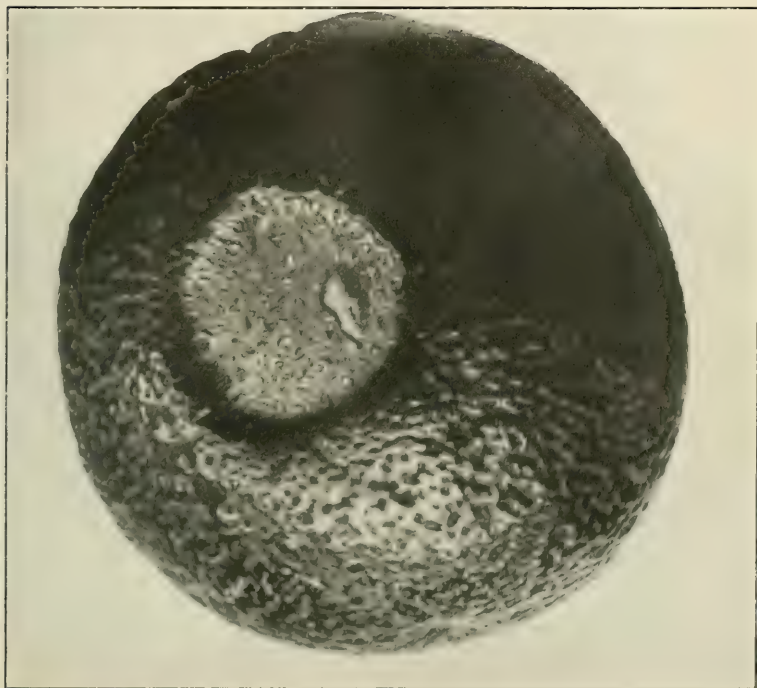


FIG. 2.—RIPE ORANGE SHOWING KATYDID SCAR AND THE BEGINNING OF SPLITTING. (ORIGINAL.)



FIG. 1.—ORANGE TREE SHOWING OUTSIDE FRUIT INJURED BY KATYDIDS. (ORIGINAL.)

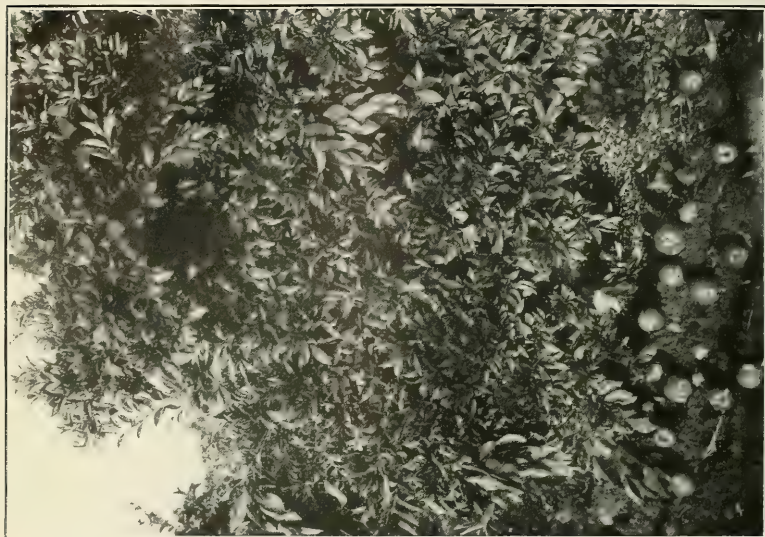


FIG. 2.—ORANGES INJURED BY KATYDIDS AND DISCARDED ABOUT THE TREES AT PICKING TIME. (ORIGINAL.)

INJURY TO ORANGES BY KATYDIDS.



FIG. 1.—ORANGE LEAVES INJURED BY KATYDIDS. (ORIGINAL.)



FIG. 2.—THE FORKED-TAILED KATYDID (*SCUDDERIA FURCATA*): ADULT FEMALE. ABOUT TWICE NATURAL SIZE. (ORIGINAL.)

THE FORKED-TAILED KATYDID AND DAMAGE TO ORANGE LEAVES.

has been reported by Riley¹ as feeding mostly on oak leaves and showing a preference for depositing its eggs therein.

LIFE HISTORY AND HABITS.

THE EGG.

The egg (fig. 3) may be described as follows: Length, 4.5 mm.; breadth, 1.87 mm.; greatest thickness (when first deposited), 0.5 mm. Light gray; smooth, glistening; flat, ovoid, slightly reniform.

The egg is completely hidden from ordinary observation in the plant tissues; in fact, most eggs are inserted into the edges of the older and rather tough leaves, between the upper and lower surfaces. They are at first difficult to detect, but after practice their presence may be recognized by certain outward indications. The edge of the leaf where the egg is inserted is generally slightly chewed away, and with a lens the sharp tip of the egg may often be seen protruding from the cut. When the chewed places are not in evidence, the presence of an egg may be recognized by a slight oval swelling in the edge of the leaf. More rarely from one-fourth to one-half of the egg may be found protruding from the edge of the leaf. Occasionally two eggs are deposited side by side, and in course of growth they may break through the epiderm and remain exposed along an entire side. A suspected leaf, when held to the sun, will show the complete outline of any eggs which may be present. Eggs are occasionally found inserted into the angular edges of tender orange stems. At times the female eats a hole through a leaf and deposits eggs in the edge of the hole. Most eggs will be found in leaves well concealed within the spread of the tree, being thus protected, as well as may be, from enemies and frost. The number deposited in a single leaf ranges from 1 to 10, rarely more than 10; the average greatest number being but 3.

During the first warm days of spring the eggs begin to swell through the development of the embryo. Shortly before hatching the egg is almost three times as thick laterally as when first deposited, the swollen areas in the leaf being therefore much more easily detected at this time than in fall or winter. In hatching, the two lateral halves of the eggshell separate along the outer third of their length, and the nymph slowly forces its way out head foremost. Experiments with a large number of eggs showed that hatching may take place even in leaves which have fallen to the ground and become dried out, provided they are kept fairly moist by exposure to the



FIG. 3.—Eggs of the fork-tailed katydid (*Scudderia furcata*) in position in an orange leaf. About twice enlarged. (Original.)

¹ Riley, C. V. Sixth Annual Report on the Noxious, Beneficial, and other Insects of the State of Missouri, p. 164-166. Jefferson City, Mo., 1874.

winter rains. If, however, the leaves are kept perfectly dry, a large percentage of the nymphs fail to extricate themselves from the egg-shell. This observation suggests the possibility that the species may successfully pass the winter in the egg stage even in deciduous leaves and in its most northerly range, provided these leaves are sufficiently protected from freezing by a covering of dead leaves and snow.

INCUBATION PERIOD.

Eggs have never been observed to hatch during the year they were deposited, and in the San Joaquin Valley they invariably pass the winter in the leaves on the citrus tree. The average duration of the egg stage, as determined in 1911 and 1912 from 68 eggs deposited between July 14 and August 6, was 286 days. Eggs deposited in July averaged about 290 days; those deposited in August, about 275 days. Those deposited later in the year undoubtedly have a shorter duration, since the period of hatching for all is short. In general, the incubation period lasts from the maximum period of deposition, about the middle of August, to the maximum period of emergence, which, in 1912, was about the middle of May, or 275 days.

ENEMIES OF THE EGG.

A small chalcidid parasite, determined by Mr. J. C. Crawford as belonging to the genus *Anastatus*, is the most important, and indeed the only enemy of the egg discovered during the investigation. This parasite, though perhaps the most important natural check to the species, is much more effective in checking the angular-winged katydid, to which it largely confines its attacks. On March 22, 1912, a quantity of orange leaves, each containing one or more eggs of *S. furcata*, was gathered and kept in condition for the hatching of the eggs. On April 2 adult parasites began to emerge from these eggs and continued to do so for one and one-half months, or until May 18. The proportion of eggs parasitized in the lot under observation was 25 per cent. The eggs were taken at random from all parts of an orchard, and it seems reasonable to assume that fully 25 per cent of all the eggs in this orchard were parasitized.

General appearance of adult parasites.—The little parasites running over the orange leaves resemble small, winged black ants. They are very active, glossy black, reflecting metallic bronze-green in the sunlight. They have two pairs of membranous wings, the fore pair in the female being almost covered by a large, brownish spot; both pairs are transparent in the male. The female is about one-eighth inch long, the male considerably smaller. Only one parasite issued from a single katydid egg in any case observed. The insect escapes from the side of the parasitized egg. The oviposition of *Anastatus* has not been observed.

THE YOUNG.

GENERAL APPEARANCE.

The young katydids of this species vary in length from one-sixth to three-fourths inch, depending on their age. Immediately after issuing from the egg they are of a pale flesh color, without visible vestige of wings. The head and mouth parts are large in proportion to the rest of the body; the antennæ are long and slender and usually directed forward. The larger nymphs, with rudimentary wings or "wing-pads," are bright green, closely matching the color of the orange leaves on which they rest. They resemble somewhat the young of the short-horned grasshoppers (Acridiidae), except for the long, slender antennæ. They usually remain motionless upon the leaves or move over to the side away from the observer when too closely approached. Ordinarily at the approach of danger they become perfectly motionless in every part and, simulating the leaf color closely, are readily overlooked. When sufficiently disturbed, however, they show ample power as leapers, and will jump a foot or more.



FIG. 4.—The fork-tailed katydid (*Scudderia furcata*): First-instar nymph. About three times natural size. (Original.)



FIG. 5.—The fork-tailed katydid: Basal segments of the antenna of first-instar nymph. Greatly enlarged. (Original.)

DESCRIPTION OF INSTARS.

The young katydid grows slowly for an average period of about 73 days, during which time it molts six times before final emergence as a mature insect.

First instar (fig. 4).—Measurements: Greatest breadth of head, 1.10 mm.; greatest breadth of abdomen, 0.75 mm.; length of body, 4.10 mm.; length of pronotum, 0.70 mm.; length of posterior femur, 4.20 mm.; length of antenna, 10 mm. Just after issuance from the egg the nymph is of a pale flesh color. The legs, head, and thorax are irregularly marked with small blotches of red, purple, and white; the abdomen, with about ten longitudinal rows of minute red and white spots, the most conspicuous of which are one row of dark spots on either side of the middorsal yellow

line and two rows of white spots below these on either side of the abdomen. The newly issued nymph is about one-sixth inch long. The fastigium, which is most prominent in this stage, is about one-half as long as the club-like basal segment of the antenna (fig. 5). Antenna with five distinct, broad white rings at regular intervals from tip to base, and with two narrow, less distinct white rings near the base; spaces between the rings dark purple. Head broad, thorax comparatively narrow, abdomen considerably enlarged toward tip. The lateral edges of sclerites

forming the dorsum of the mesothorax and metathorax appear as little flap-like, evenly rounded processes folded down over the upper portion of the episterna and epimera of their respective segments. These semicircular processes are the wing rudiments and are distinctly characteristic of this instar.

Second instar (fig. 6).—Measurements: Breadth of head, 1.3 mm.; greatest breadth of abdomen, 1.4 mm.; length of body, 6 mm.; length of pronotum, 1.1 mm.; length of posterior femur, 6.1 mm.; length of antenna, 14 mm. The markings on the body are the same as in the preceding instar, but the ground color of the abdomen is bright green, making the spots on it less conspicuous. The small, flaplike wing rudiments are now almost equilaterally triangular, with nearly pointed and but very slightly rounded tips. The bright green color of the abdomen

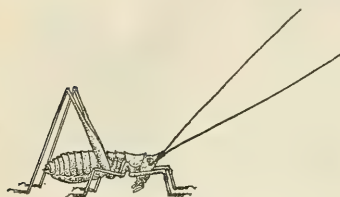


FIG. 6.—The fork-tailed katydid: Second-instar nymph. Somewhat more than twice enlarged. (Original.)

and the triangular shape of the wing-pads readily distinguish this stage from the preceding one. Just after the first molt the nymph is about one-fourth inch long.

Third instar (fig. 7).—Measurements: Length of body, 7.4 mm.; length of pronotum, 1.55 mm.; length of posterior femur, 7.5 mm.; length of antenna, 17 mm. The general color and markings of the body are as in the second instar, the intensity of the green coloring varying in different individuals. In this and succeeding instars the head and abdomen are less broad compared with the thorax than in instars I and II. The wing rudiments are triangular as in the second instar, but their hind margins extend downward and very slightly forward, while the front margin extends more abruptly backward than in preceding stages, thus making the sides unequal in length. Faint evidences of wing-veins may be distinguished at this stage. Just after molting to this instar the nymph is about one-third inch long.



FIG. 7.—The fork-tailed katydid: Third-instar nymph. Three times natural size. (Original.)

Fourth instar (fig. 8).—Measurements: Length of body, 10 mm.; pronotum, 2.3 mm.; posterior femur, 10.8 mm.; antenna, 24 mm. Color as in preceding instar. Wing-pads appressed to sides of mesothorax and metathorax as in preceding instars, but both front and hind margins extending downward and backward; posterior pair reaching well over on the sides of the first abdominal segment. About eight veins can be readily distinguished in the hind wings and a few

are faintly visible in the forewings. The pronotum covers about one-half the dorsum of the mesothorax. The sexes can be distinguished in this stage by the appearance of the external genitalia. Just after the third molt the nymph is about two-fifths inch long.

Fifth instar (fig.

9).—Measurements: Length

of body, 12.5 mm.; pronotum,

3.1 mm.; posterior femur, 13

mm.; antenna, 26 mm. In this

instar the position occupied by

the wing-pads is different from that in any of the earlier instars.

They now lie partly over the abdomen in a tectiform position, this

change being brought about by the previously outwardly exposed

sides being brought out, upward, and in leaving the inner sides

exposed roof-shape above the body. The tips of the posterior

wing-pads now reach to the hind margin of the second abdominal

segment; wing-pads similar in shape, in position relative to the body,

and in venation to the adult wings.

Pronotum completely covering the dor-

sum of the meso-

thorax. The young

of this instar are

about one-half inch

long shortly after

the molt.

Sixth instar (fig.

10).—Measurements:

Length of body, 16

mm.; pronotum, 4.5

mm.; posterior fe-

mur, 18.5 mm.; an-

tenna, 3.9 mm. In

this instar the nymphs resemble adults in almost every particular

except the smaller size of the wings. Just after molting the wings

extend rooflike over the abdomen to the ninth segment, the dorsal

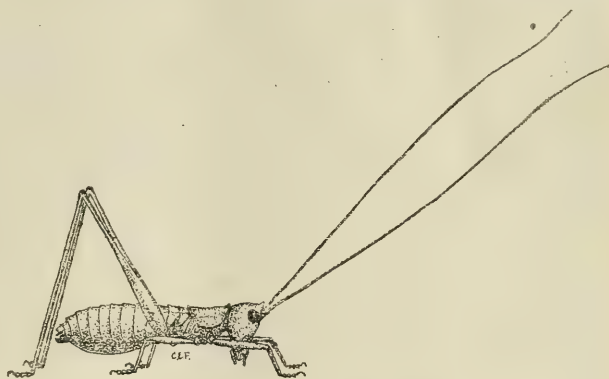


FIG. 8.—The fork-tailed katydid: Fourth-instar nymph. About three times natural size. (Original.)



FIG. 9.—The fork-tailed katydid: Fifth-instar nymph. About three times natural size. (Original.)

edges meeting near their tips. With feeding and growth of the nymph the abdomen elongates without a corresponding growth of the wings, with the result that the latter reach only about to the sixth abdominal segment just before transformation to the adult. The prothorax extends slightly over the dorsum of the metathorax. The white rings on the antennæ, which have grown gradually fainter with each succeeding molt, are now but faintly visible. The external genitalia, the ovipositor in the female and the forked, supraanal spine in the male, appear to be almost as fully developed as in the adult. The nymph is about five-eighths inch long just after the molt to this instar.



FIG. 10.—The fork-tailed katydid: Sixth-instar nymph. About three times natural size. (Original.)

DURATION OF INSTARS.

The duration of instars, averaged from all our records, was as follows: Instar I ranged from 10 to 35 days, with an average of 18.8 days; instar II ranged from 8 to 13 days, with an average of 9.7 days; instar III ranged from 4 to 12 days, with an average of 7.1 days; instar IV ranged from 6 to 10 days, with an average of 8.3 days; instar V ranged from 3 to 15 days, with an average of 10.4 days; instar VI ranged from 12 to 20 days, with an average of 14 days. The complete nymphal stage required from 58 to 88 days. Nymphs issuing early in the spring were slower to become adults than those issuing later when the average temperatures were higher.

MOLTING.

After feeding for from 1 to 3 weeks the nymph ceases to eat and remains sluggish for from 24 to 48 hours. The skin then splits along

the middorsal line from between the eyes to a point between the posterior wing-pads. The insect hangs helplessly, head downward, suspended by the posterior claws, and gradually works its way out of the dead skin. The head, thorax, fore-legs, intermediate legs, wings, abdomen, and hind legs are freed from the exuvium in the order named. During the entire process the antennæ are held lightly between the maxillary palpi and pulled and guided carefully from their position along the ventral surface of the body.

ENEMIES OF THE NYMPH.

A common gray jumping spider, determined by Mr. Nathan Banks, of the Bureau of Entomology, as *Thiodina puerperis* Htz., has been observed to capture the small nymphs of the first instar. This active, solitary spider is quite numerous on orange trees in the San Joaquin Valley, and feeds upon insects of several orders, injurious and beneficial alike. The very young spiders capture insects as minute as the citrus thrips.

In 1911 a small chipping sparrow was noted in some abundance among trees of various katydid-infested orchards, and was apparently very busily capturing katydids. Birds are undoubtedly the most important enemies of the katydid in this section.

THE ADULT.

GENERAL APPEARANCE.

The adults (Pl. III, fig. 2) are dark green, their color blending almost perfectly with that of the orange leaves. They habitually seek the shady interior of the tree during the heat of the day, thus adding to the difficulty of discovery, even when fairly abundant. Their length is about $1\frac{1}{2}$ inches from vertex to tip of wings. When they are at rest, the wings, which are narrow and rounded at the tips, are closely folded along the sides of the body. In flight the stiff, outstretched wings and the habit of sailing for considerable distances with scarcely any wing movement give them a fancied resemblance to a monoplane.

EMERGENCE AND MATING.

As a rule most of the nymphs transform to the adult stage early in the summer, though the exact time of beginning emergence varies more or less in different years. In 1912 adults were fairly numerous by June 15 and practically all of the insects were in the adult stage by July 5. In 1911 the period of emergence was slightly later than in 1912, and nymphs were found in the field until about July 17.

Mating usually takes place about 20 days after emergence, the time elapsing between the last molt and the first copulation varying from 14 to 40 days. Females which have recently mated can usually,

if not always, be detected by the extrusion near the base of the ovipositor of a bilobed translucent, jellylike mass of unknown character, which is visible for several hours.¹

Specimens in captivity have mated as often as six times in a period of about 120 days. Union of the sexes perhaps occurs less often in the field. The stridulation note of the male is a short, soft rasp, usually given one, two, or three times in succession. The note is produced by rubbing the short, filelike process, extending diagonally across the under surface of the forewings, over the thin margin of the hind wings. At times it appears to be a sexual call, at other times merely a note of alarm; it is most persistent at night.

OVIPOSITION.

Oviposition, which has been observed by the writers many times, has already been described in some detail by Riley.² Variations from Riley's account were noted in the orange groves near Lindsay, Cal., as follows: For a period of about 10 seconds the female generally cleanses, or possibly lubricates, the convex edge and tip of the ovipositor with her mouth before the deposition of each egg. The ovipositor is always held firmly between the mandibles from the moment its tip touches the edge of the leaf until the blade is finally withdrawn from the latter. As the ovipositor is forced between the leaf surfaces the two pairs of blades comprising it move slowly back and forth, alternately, over each other with a distinct though slight rotatory motion. The apical third of two of the blades is finely notched, sawlike, along the concave margin, the other pair being similarly notched along the convex margin. At the beginning of oviposition the ovipositor is worked into the leaf for almost its entire length, thus forming a pocket to contain the egg. Without pause the organ is then withdrawn to half its length, and the abdomen begins to expand and contract rhythmically, forcing the egg between the blades of the ovipositor into the cavity in the leaf. The complete operation of depositing one egg requires about four and one-half minutes.

Rate of oviposition and number of eggs deposited by single females.—A female of *Scudderia furcata* has been seen to deposit as many as 9 eggs in 45 minutes. This high rate of oviposition is not, however, long maintained, and after depositing such a number the female usually ceases to oviposit for from one to four days. Eggs are seldom deposited for more than three days in succession. During the summer

¹ Similar protrusions have been noted following mating in the females of other Locustidae. The writers have observed it on the female of *Microcentrum rhombifolium* Sauss.; C. P. Gillette has seen and described it on *Anabrus simplex* Haldeman; R. E. Snodgrass has noted the phenomenon in connection with the mating of *Peranabrus scabricollis* Thomas; and it had previously been observed in *Scudderia furcata* Brunn. by A. N. Caudell.

² Loc. cit. Due to a misidentification the name here used is *Scudderia curvicauda*.

the usual number of eggs, from 1 to 3, are laid overnight, at which time oviposition mostly occurs. Oviposition decreases during the fall months and usually ceases entirely about midwinter. Females which have ceased to oviposit in winter may be induced to begin again by placing them in an artificially warmed atmosphere. Thus, one of a number of females which had ceased to oviposit about the middle of November, when taken from a temperature of 40° F., early in December, and placed in a room heated to 75° F., began to oviposit and laid 8 eggs in the course of an hour. A single female in the course of her life deposits, on an average, about 175 eggs. Infrequently individuals held in captivity from the middle of July to the following December have deposited about 230 eggs. The following complete individual records were obtained from specimens which emerged in captivity and were kept there, under nearly field conditions, until death:

TABLE I.—*Oviposition record of the fork-tailed katydid, Lindsay, Cal., 1912.*

No. of specimen.	Number of eggs deposited.	No. of specimen.	Number of eggs deposited.
1	169	10	206
2	172	11	74
3	121	12	140
4	174	13	230
5	114	14	87
6	64	15	142
7	73	16	239
8	132	17	61
9	57	18	159

Most of the eggs of this species are deposited during the period from the latter part of July to the last of September, though oviposition still occurs as late as the first week in December in warm winters, and adults have been found ovipositing as early as June 18.

LENGTH OF LIFE OF ADULTS.

Adults reared in screened cages, protected from their natural enemies and given an abundance of fresh food daily, lived, on an average, 125 days, or a little over four months. In a few exceptional cases individuals lived from 150 to 160 days—162 days in the case of a single specimen being the record longevity.

ENEMIES OF THE ADULT.

Birds undoubtedly play an important part in reducing the number of adults each year. Under field conditions adults are less numerous in October and November than in July and August, yet specimens protected by large screen cages live through October and most of November as actively as during the first few weeks of their adult life. In certain orchards where the infestation was particu-

larly bad in 1911 and 1912 large numbers of adult katydids disappeared in August and September. At about the same time large numbers of small birds of an undetermined species were noted in and about these orchards. These little birds were unquestionably responsible for the disappearance of katydids.

SEASONAL HISTORY.

As there is but one generation of the fork-tailed katydid annually, the duration of the life cycle is approximately one year. The average life cycle, as determined from a number of complete rearings in 1911 and 1912, was 367 days, ranging from 343 to 383 days. The first nymphs to appear issued about April 20, the majority issuing during May. Nymphs are most abundant in May and June, but have occasionally been seen as late as August 15. The first adults appear early in June, are fairly numerous by the last of June, and most abundant during July and August. They can be found without much difficulty in September and more rarely in October. The last specimens of the season were captured December 3. A few have been kept alive in screen cages until early January.

THE ANGULAR-WINGED KATYDID.

NATURE AND EXTENT OF INJURY.

The angular-winged katydid (*Microcentrum rhombifolium* Sauss.) somewhat closely resembles the fork-tailed katydid and is closely associated with the latter on orange trees in the San Joaquin Valley. It is, however, larger than the fork-tailed katydid and may be readily distinguished from that insect by its size, broader wings, and in the nymph by its hunchbacked appearance. Although responsible for a certain amount of injury to orange trees annually, it attacks only the foliage and rarely does enough damage to cause alarm. This insect has been present in Florida orange groves for years without, except in rare cases, causing sufficient damage to attract attention. This is also the case in California. The observations of the writers indicate that the minor position of the angular-winged katydid as a pest is largely due, first, to the high percentage of parasitism suffered by the eggs; and, second, to the fact that the insect does not attack the fruit. That it might injure the fruit if able to increase to the point of crowding is quite possible. The insect is also exposed to the attacks of various enemies, chiefly birds, because of its large size and slowness of movement. The first-instar nymphs feed principally if not wholly upon the leaf surface, removing merely a chlorophyll layer. Later stages gnaw clear through the leaves, filling them with ragged holes, and destroy a larger amount of foliage in proportion to their number than does the fork-tailed katydid. The insect has never been seen to attack blossoms or fruit.

FOOD PLANTS.

In the San Joaquin Valley orange section the angular-winged katydid, like the forked-tailed katydid, confines itself all but exclusively to orange trees. Its eggs have been found a few times upon an undetermined native weed, the latter always growing near orange trees. Adults have been found upon grapevines adjoining an orange grove, and males have repeatedly been heard loudly stridulating in large pepper trees (*Schinus molle*) about Lindsay, Cal. According to Riley¹ an allied species, *Microcentrum retinerve* (Burm.), feeds upon a great variety of foliage, including oak, apple, and cherry.

DISTRIBUTION.

The angular-winged katydid has apparently about as wide a range as *Scudderia furcata*, having been reported from the New England States, Florida, and California. It occurs throughout the central California citrus belt with the fork-tailed katydid, though it is not so often found because less numerous.

LIFE HISTORY.

THE EGG.

The egg (Pl. IV, fig. 1) may be described as follows: Length, 5.18 mm.; breadth, 2.47 mm.; thickness when first deposited, 0.5 mm.; thickness just before hatching, 2.2 mm. Color light grayish brown; elongate ovoid, flat to almost cylindrical laterally, depending upon the degree of development.

The eggs are glued in double rows along the sides of twigs from one-eighth to one-fourth inch in diameter. These selected twigs may be inside the leaf shelter of the tree or on the exterior. There may be from 3 to 28 or more eggs in a batch, each egg overlapping the one above it. The two rows always occur if more than one egg is deposited, each egg of one row alternating with an egg in the other row. The larger egg groups of this insect, composed of 24 or more eggs, each about one-fifth inch long, are decidedly conspicuous.

INCUBATION PERIOD.

The average duration of the egg stage is about 225 days. Eggs deposited the last of September hatch in about 228 days, while those deposited about the middle of October hatch in approximately 212 days. The time required for incubation thus depends upon the time of season deposited, the period of hatching being shorter than the period of deposition. Eggs laid from September 20 to September 30 hatched from May 10 to 15, while those deposited between October 20 and 30 hatched from May 15 to 20.

¹ Op. cit., p. 155-161.

HATCHING.

When the egg is ready to hatch, the lateral halves split at their juncture along its edge for about one-third the length from the upper end, the nymph slowly forcing itself through the opening thus made.

ENEMIES OF THE EGG.

The greatest natural check to the increase of the angular-winged katydid in California is the egg parasite, *Anastatus* sp., already referred to in connection with *Scudderia furcata*. *Anastatus* parasitizes a large percentage of all eggs deposited by this insect each year. It is quite usual to find large batches of katydid eggs, each egg showing the small, circular exit hole of the parasite (Pl. IV, fig. 1). It is, in fact, rare to find eggs of this katydid entirely free from evidence of parasitism. *Anastatus* oviposits in the katydid eggs in September and October, the larva feeding upon the egg contents during the remainder of the fall and the adult emerging the following spring. All reared specimens have emerged between March 19 and May 18. It seems probable that 80 per cent or more of all eggs deposited by *M. rhombifolium* are destroyed by this little insect. For example, a lot of eggs collected in widely separated locations in the fall of 1911 produced 43 adult *Anastatus*, representing 86 per cent parasitism. Of another lot of 109 eggs 35 per cent produced living parasites and the remainder failed to hatch.

THE NYMPH.

DESCRIPTION OF INSTARS.

The nymph of the angular-winged katydid may be easily distinguished from that of the fork-tailed katydid by its plump body and highly arched back, which gives it a decidedly humpbacked appearance. The nymphs vary in length from one-sixth to three-fourths inch, depending upon the stage of development. Their color is grass-green throughout, including the long, threadlike antennæ. There are six periods of development, or instars, which may be described as follows:



FIG. 11.—The angular-winged katydid (*Microcentrum rhombifolium*): First-instar nymph. Slightly over twice natural size. (Original.)

First instar (fig. 11).—Measurements: Length of body, 4 mm.;

length of head (vertex to tip of jaws), 2 mm.; length of pronotum, 0.72 mm.; length of posterior femur, 4.75 mm.; length of posterior tibia, 5 mm.; length of antenna, 16 mm.; subovate, convex along dorsum and nearly flat along ventral surface. Color grass-green,

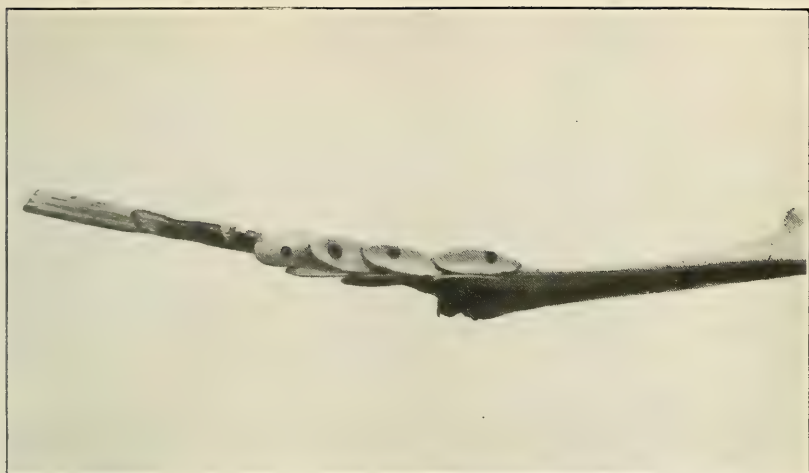


FIG. 1.—EGGS OF THE ANGULAR-WINGED KATYDID (*MICROCENTRUM RHOMBIFOLIUM*), SHOWING EXIT HOLES OF THE PARASITE, *ANASTATUS* SP. TWICE NATURAL SIZE. (ORIGINAL.)

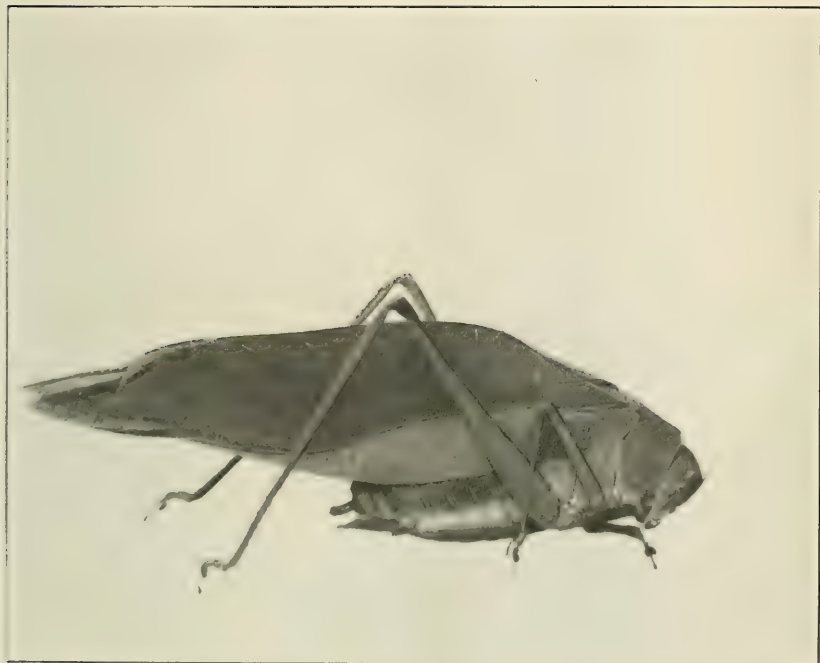


FIG. 2.—THE ANGULAR-WINGED KATYDID: ADULT MALE. THREE-FOURTHS ENLARGED. (ORIGINAL.)

THE ANGULAR-WINGED KATYDID.

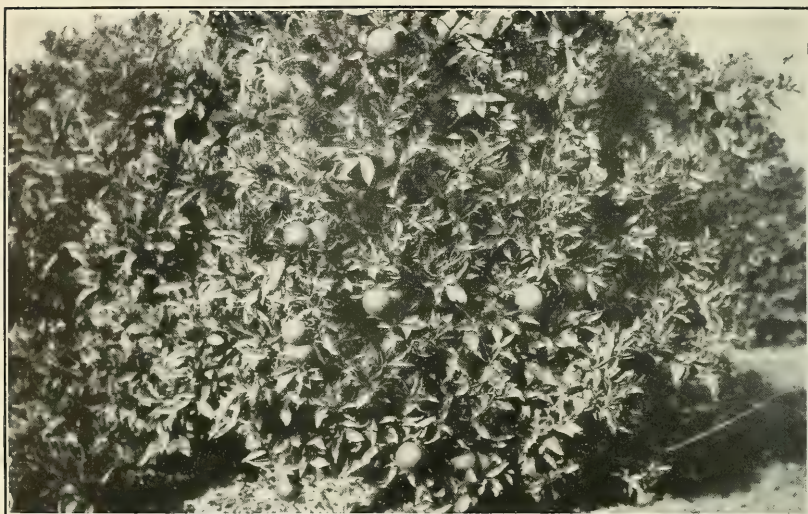


FIG. 1.—A ROW OF SPRAYED ORANGE TREES BEFORE PICKING. [THE TREE IN FOREGROUND REPRESENTATIVE OF ALL SPRAYED TREES.] (ORIGINAL.)



FIG. 2.—VIEW IN AN EXPERIMENTAL ORCHARD IN CALIFORNIA. (ORIGINAL.)

CONTROL OF KATYDIDS ON ORANGES.

with minute black dots in longitudinal rows, forming one crossrow upon each abdominal segment near hind margin; legs marked with more conspicuous black dots.

Second instar (fig. 12).—Measurements: Length of body, 6 mm.; length of head, 2.4 mm.; length of pronotum, 1.14 mm.; length of posterior femur, 5.8 mm.; length of posterior tibia, 6 mm.; length of antenna, 21.96 mm. Shape and color of body about as in first instar.

Third instar (fig. 13).—Measurements: Length of body, 7.5 mm.;

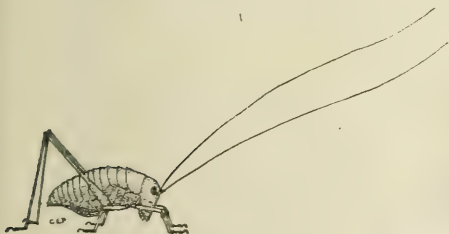


FIG. 12.—The angular-winged katydid: Second-instar nymph. Somewhat over twice natural size. (Original.)



FIG. 13.—The angular-winged katydid: Third-instar nymph. Nearly three times natural size. (Original.)

length of head, 2.9 mm.; length of pronotum, 1.6 mm.; length of posterior femur, 8 mm.; length of posterior tibia, 8 mm.; length of antenna, 20.25 mm. Color and shape of body as before, except that black spots are less conspicuous.

Fourth instar (fig. 14).—Measurements: Length of body, 10 mm.; length of head, 3.75 mm.; length of pronotum, 2.66 mm.; posterior femur, 10 mm.; posterior tibia, 11 mm.; antenna, 20 mm. General color of body light green, merging into yellow on sides of abdominal segments; abdomen white beneath, or nearly so. Wing-pads sufficiently developed to be distinctly recognizable as such, hind pair showing well-developed veins and just overlapping first abdominal segment; tips of wing-pads directed downward and slightly backward.



FIG. 14. The angular-winged katydid: Fourth-instar nymph. Two and one-half times natural size. (Original.)

Fifth instar (fig. 15).—Measurements: Length of body, 15 mm.; length of head, 4.5 mm.; length of pronotum, 4 mm.; posterior femur, 13.25 mm.; posterior tibia, 14.5 mm.; antenna, 29 mm.

Color about as in preceding instar; body more strongly arched. Wing-pads more distinctly veined, their tips directed backward over the abdomen, reaching to middle of second segment.



FIG. 15.—The angular-winged katydid: Fifth-instar nymph. Two and one-half times natural size. (Original.)

Sixth instar (fig. 16).—Measurements: Length of body, 17 mm.; length of head, 5.7 mm.; length of pronotum, 5 mm.; posterior femur, 16.5 mm.; posterior tibia, 17.7 mm.; antenna, 37.4 mm. Body strongly arched above, sloping about equally abruptly in both

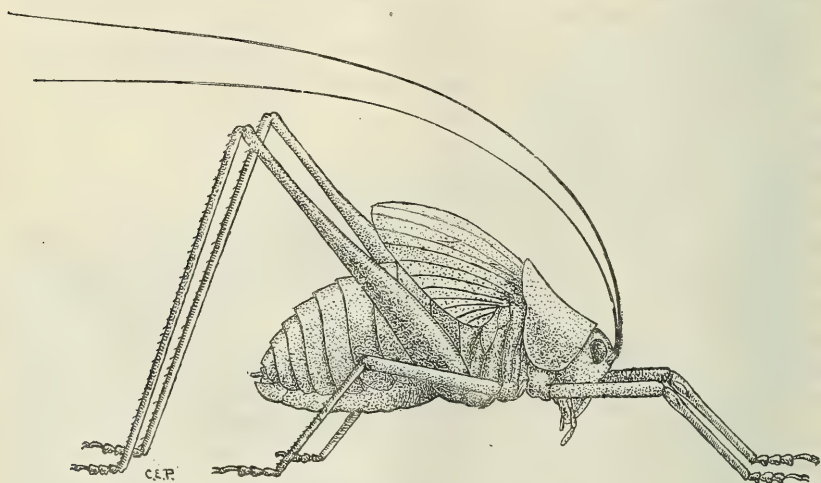


FIG. 16.—The angular-winged katydid: Sixth-instar nymph. Almost three times natural size. (Original.)

directions from second abdominal segment; wings projecting upward and backward at an angle from abdomen; tips considerably elevated above latter.

Nymphal instars each described from a single specimen shortly after molting.

DURATION OF INSTARS.

The average duration of the nymphal instars of the angular-winged katydid, as determined from a number of individual rearings, was as follows: Instar I, 13.8 days; instar II, 8.6 days; instar III, 9.5 days; instar IV, 10.2 days; instar V, 13.7 days; instar VI, 17.2 days. The average duration of the complete nymphal stage is therefore 73 days, or about $2\frac{1}{2}$ months. Molting is accomplished in about the same manner as by the fork-tailed katydid (see pp. 10-11. The nymph always eats the greater part of its cast skin after each molt, rejecting only the mandibles, claws, and certain hard parts of the head cast.

THE ADULT.

GENERAL APPEARANCE.

The body of the adult is broad and compact, and comparatively very wide dorsoventrally (Pl. IV, fig. 2). The humpbacked appearance so characteristic of the later stages of the nymph is retained, but to a lesser degree, owing to the broadly rounded angle of the forewings. The hind wings extend the full length of the body beyond the tip of the abdomen. The color is uniform grass-green over most of the body, becoming yellowish green on the ventral surface. The insect is fully 2 inches long, the wings measuring, when spread as for flight, about $3\frac{1}{2}$ inches.

MATING.

Mating rarely or never occurs earlier than 18 days after emergence, and the period between emergence and the first union of the sexes ranges from 18 to 26 days. Coitus is succeeded by the extrusion of a small, bilobed mass of albuminous material, which, as in *Scudderia furcata*, may be seen clinging to the abdomen at the base of the ovipositor in the female for several hours subsequent thereto. The favorite time for mating is at night, when the males are very active and may often be heard sending forth a loud and sustained clatter for several hours at a time. The stridulating note, once heard, is readily recognized, and to trace it to its source will often disclose both male and female katydids, as stridulation appears to be closely connected with courtship. The stridulating song of an allied species, *Microcentrum retinerce* Burm., has been described by Riley as consisting of "a series of from 25 to 30 raspings, as of a stiff quill drawn across a file" at the rate of "about five of these raspings or trills per second, all alike, and with equal intervals, * * * the whole strongly recalling the slow turning of a child's rattle." This description is equally applicable to *M. rhombifolium*.

OVIPOSITION AND LENGTH OF ADULT LIFE.

In captivity females have deposited from 3 to 123 eggs each during

the course of life, and in the orchard under normal conditions they probably deposit more than the maximum number here given, since on one occasion 133 eggs, showing advanced development, were removed from the ovisac of a female which had not oviposited during her entire life in captivity. The number of eggs laid at one time varied from 3 to 28. The adults live from three to three and one-half months, and are present in the orchard almost continuously from the middle of August to the middle of November. Adults lived in screen cages from 85 to 111 days.

SEASONAL HISTORY.

Most of the eggs of this species are deposited during September and October, and all eggs secured from females in captivity in 1911 and 1912 were deposited between September 4 and October 29. The eggs hatching the following spring, the nymphs make their appearance about the first of May. They reach the maximum abundance between May 15 and July 15 and will seldom be seen after the middle of August. Adults are most numerous during the period from August 15 to October 15; they are scarce in November and rare in December, finally disappearing entirely in January.

CONTROL OF KATYDIDS ON ORANGES.

Several methods have been suggested for the control of katydids on oranges, among which the following have been found to be impractical: Destroying the nymphs by hand; gathering by hand and destroying the eggs; poisoning by the use of trap crops or by poisoned baits. It would be extremely difficult, if not impossible, to find any large percentage of eggs or nymphs, and the method would certainly prove too slow and tedious. The katydids can not be attracted from the fruit and foliage of the orange by any crop or bait while such an abundance of food so much to their liking is always at hand. Unless practically forced to quit the orange tree, they spend their entire lives upon the tree on which they are born.

SPRAYING EXPERIMENTS.

Spraying with arsenicals is generally considered to be impractical for the control of grasshoppers and locusts because of the large dose necessary to kill these robust insects and the difficulty of applying such a dose evenly and with safety to the trees. These objections would doubtless hold with the citrus katydids if the spraying were done after the insects had reached an advanced nymphal or the adult stage. They do not hold, however, when the trees are properly sprayed while the insects are still largely in the first, second, or third nymphal instars.

PRELIMINARY TESTS WITH ARSENICALS.

Four groups of 10 Washington navel trees each were sprayed on April 15, 1912, for the purpose of determining the maximum strength of the different arsenicals that could be used with safety to the trees and to compare the adhesive qualities of the insecticides. The spraying was done in bright, warm weather and the trees were thoroughly drenched. The test trees were examined on April 19, and although covered with tender, new leaves not the slightest trace of burning resulted. Subsequent examinations in no case revealed burning or damage resulting from the spray application. It was later found safe to use considerably stronger solutions of the arsenicals, the maximum strengths of which were (1) arsenite of zinc, 2 pounds (powdered) per 100 gallons of water, and (2) arsenate of lead, 8 pounds (dry) per 100 gallons of water. The distribution of the arsenicals over the leaf surface after the spray dried did not seem entirely satisfactory, especially on the young leaves, whose waxy surface had caused the water to gather in drops, leaving the poison in spots. The addition of lime-sulphur solution to the arsenical sprays and the regulation of the nozzles so as to deliver a moderately fine spray remedied this objection.

PLAN OF EXPERIMENTS.

The principal spraying experiments conducted against the katydids are outlined in Table II. Each of the sprayed plats consisted of two rows of 33 trees each, or 66 trees to the plat. Three pairs of rows of trees extending through the midst of the sprayed area and the trees adjoining the sprayed area on the west were left unsprayed as checks. (See experimental orchard, Pl. V, fig. 2.)

TABLE II.—*Plan of spraying experiments against citrus katydids, Lindsay, Cal., 1912.*

No. of plat.	Insecticides in gallons and pounds per 100 gallons of water.		
	Lime-sulphur solution.	Arsenite of zinc.	Arsenate of lead.
	Gallons.	Pounds.	Pounds.
1	2	2	.....
2	2	3	.....
3	2	4	.....
4	2	.....	4
5	2	.....	6
6	2	.....	8
7	.....	2	.....
8	.....	3	.....
9	.....	.....	.....

Plats 1, 2, 4, and 5 received two applications containing lime-sulphur and arsenicals and one application of lime-sulphur alone; plats 3 and 6 received one application containing both lime-sulphur and arsenicals and two applications of lime-sulphur alone; plats 7, 8, and 9 received only two applications of arsenicals alone. The chief purpose of adding lime-sulphur to the sprays was to make them effective against the citrus thrips. The third application was directed solely against this insect, only two applications of arsenicals being made in any case. The applications were timed, also, partly with a view to controlling thrips as well as katydids, and the dates of beginning were May 22, June 3, and June 24, respectively.

RESULTS.

The efficiency of the sprays in killing katydids was determined by a comparison of the number of living insects occurring in the sprayed and unsprayed blocks some days after spraying was completed. Arsenite of zinc at the rate of 2 pounds per 100 gallons killed 93.1 per cent of the fork-tailed katydids and 100 per cent of the angular-winged katydids. Arsenate of lead at the rate of 4 pounds per 100 gallons killed 100 per cent of the insects in each case.

The results of the season's spraying work were principally manifested in three ways: (1) By preventing a complete loss of a certain amount of fruit by dropping; (2) by almost complete prevention of katydid injury to the mature fruit and the leaves and reduction in the amount and severity of thrips injury; and (3) by improvement in the amount and vigor of growth of the sprayed over the unsprayed trees.

PREVENTION OF DROPPING.

During July, fruits injured by both katydids and thrips were very conspicuous on the unsprayed trees, at once attracting the attention when one entered the orchard. While in the orchard on August 9 the senior writer noted that badly injured outside fruit was decidedly less in evidence on unsprayed trees than had been previously the case. The cause of this disappearance of fruit was soon found; it had fallen to the ground. By counting all the fruit on and under 10 unsprayed trees it was found that 18.7 per cent of the crop had fallen from these trees. Examination of the fruit which had fallen, for the location of the insect injury, disclosed 62.8 per cent of it full of holes, while 83.3 per cent were severely marked by thrips. Many of these fruits had been eaten into near the point of attachment to the stems. However, much of the dropped fruit during this period was caused by thrips injury, the most severe dropping due to katydids coming earlier in the season when very small fruits were chewed to pieces by these insects. At all events, the 18.7 per cent of dropped

fruit at this time was principally due to katydids and thrips. No fruits had fallen at this time from sprayed trees, as examination of the ground under 15 trees disclosed.

At picking time it became evident that a much larger saving of fruit than that just indicated resulted from spraying. During October and November all the fruit of all sprayed plats and checks was counted, from which it was found that from 60 to 100 per cent more fruit was produced in each of the sprayed plats than in their unsprayed checks. (See Pl. V, fig. 1.) The trees of the different plats varied greatly in size and condition, however, and it was therefore necessary to know how many trees in each plat produced the fruit of that plat. By eliminating the stunted, rebudded, and dead trees, resets, and blank spaces in each plat it was found that the full-bearing, unsprayed trees matured only 54.2 per cent, or just a little over half as many oranges per tree as the full-bearing trees of the sprayed plats. The saving of crop in all sprayed plats taken together due solely to spraying was, therefore, practically 100 per cent. A greater saving was effected in plats sprayed with lime-sulphur and arsenicals mixed than in those sprayed with arsenicals alone, the former producing a little over twice as much and the latter only one and one-half times as much fruit per tree as the checks.

PREVENTION OF INJURY TO MATURED FRUIT.

The results of the spraying experiments in preventing katydid injury to the final crop of fruit were determined by examination, in the field at picking time, of all oranges in all plats. For convenience of reference these results are shown in Table III.

TABLE III.—*Results of spraying experiments with lime-sulphur and arsenicals in preventing injury to oranges by katydids, Lindsay, Cal., 1912.*

Insecticides and dilution.	Sprayed fruit.		Unsprayed fruit.	
	Percentage of sound fruit.	Percentage of culled fruit.	Percentage of sound fruit.	Percentage of culled fruit.
Plat 1: Arsenite of zinc, 2 pounds; lime-sulphur, 2 gallons, per 100 gallons water.	100.00			
Plat 2: Arsenite of zinc, 3 pounds; lime-sulphur, 2 gallons, per 100 gallons water.	99.99	0.01	80.5	19.4
Plat 3: Arsenite of zinc, 4 pounds; lime-sulphur, 2 gallons, per 100 gallons water.	99.85	.14		
Plat 4: Arsenate of lead, 4 pounds; lime-sulphur, 2 gallons, per 100 gallons water.	99.85	.14	80.9	19.0
Plat 5: Arsenate of lead, 6 pounds; lime-sulphur, 2 gallons, per 100 gallons water.	99.86	.13		
Plat 6: Arsenate of lead, 8 pounds; lime-sulphur, 2 gallons, per 100 gallons water.	99.77	.22	82.3	17.6
Plat 7: Arsenite of zinc, 2 pounds, per 100 gallons water.	99.92	.07		
Plat 8: Arsenite of zinc, 3 pounds, per 100 gallons water.	99.92	.07		
Plat 9: Arsenate of lead, 4 pounds, per 100 gallons water.	99.84	.15		
Average.....	99.88	.11	81.45	18.55

As shown in Table III, two applications of arsenite of zinc, at the rate of 2 pounds per 100 gallons plain water (plat 7) or dilute lime-sulphur solution (plat 1), gave practically the same results as one application at the rate of 4 pounds per 100 gallons (plat 3), being sufficient in each case to kill the katydids and insure approximately 100 per cent sound fruit. Two applications of arsenate of lead, at the rate of 4 pounds per 100 gallons plain water (plat 9) or dilute lime-sulphur solution (plat 4), were practically as effective as the arsenite of zinc and gave just as good results as when used at the rate of 8 pounds per 100 gallons with but one application (plat 6).

The addition of lime-sulphur to the arsenicals, besides being absolutely essential where it is desired to control both katydids and the citrus thrips, increased the adhesive quality of the arsenicals and facilitated their even distribution over the leaves and fruit. This was especially noted after a slight rain, occurring May 25, when the combination sprays appeared to be very little affected. Lime-sulphur solution itself without the addition of arsenicals proved deterrent to the katydids and measurably reduced the amount of injury to the fruit. It also, therefore, appears to have some insecticidal value against these insects.

RECOMMENDATIONS.

On the basis of the foregoing results the writers make the following recommendations for the control of katydids on oranges in the San Joaquin Valley:

1. Two applications of arsenite of zinc at the rate of 2 pounds per 100 gallons of water; or,
2. Two applications of arsenate of lead at the rate of 4 pounds per 100 gallons of water.

The first application should be made, at the latest, immediately after most of the petals have fallen; the second application, from 10 days to 2 weeks after the first. If it seems desirable to spray for the citrus thrips also, lime-sulphur should be added to the above at the rate of 2 gallons per hundred, and a third application of lime-sulphur only, at the same dilution, should be made about two or three weeks after the second.

The cost of spraying will vary somewhat according to size of trees, cost of labor, team hire, insecticides, etc., but with ordinarily good management will not exceed \$5 per acre.



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PROGRESS REPORTS OF EXPERIMENTS IN DUST PREVENTION AND ROAD PRESERVATION, 1914.

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EXPERIMENTS AT LEMON CITY, FLA.

OILS, TAR PREPARATION, CALCIUM CHLORIDE-CORALLINE ROCK.¹

The second series of experimental bituminous treatments of coralline rock roads in Dade County, Fla., under the direction of the United States Office of Public Roads, was installed on Biscayne Drive about one-quarter of a mile north of Lemon City. The bituminous materials used were several barrels of the oils remaining from

NOTE.—This bulletin reports the results from a number of experiments in dust prevention and road preservation conducted by the Office of Public Roads in 1914. The materials used and methods employed in the experiments, the several kinds of roads and varying conditions of traffic, and analyses of materials and cost data are given.

¹ Information regarding a similar series of experiments conducted at Miami, Fla., in 1913, will be found in Bulletin of the United States Department of Agriculture No. 105.

the 1913 experiments at Miami and two water-gas tar products donated by the manufacturers for this purpose. The oils had been stored without protection from the weather, and were in poor condition, principally through the presence of water.

The excellent results obtained in experiment No. 6 of the original series of experiments at Miami could be attributed beyond question to the use of screened rock instead of the "run of the bank" material used in the other experiments. Consequently only the screened-rock type of construction was followed in these experiments. The rock was quarried from the Lemon City pit, which was the nearest source of supply. It was comparatively soft and decidedly unsuitable for bituminous work of this nature, due to its tendency to crush to powder when the screened-rock course was even lightly rolled to make it conform to cross section. In some portions this created a surface condition similar to that existing in experiments 3, 4, and 5 at Miami, described in the previous report. This soft quality and the presence of a considerable proportion of fine material, which it was found impracticable to screen out, made the surface very susceptible to the binding effects of rain.

The work began at station 0+00 at the north end of the project on January 6 and continued intermittently until February 7.

The general method consisted in scarifying and regrading the old surface, after which a course of new screened rock was spread to a loose depth of $2\frac{1}{2}$ inches. This course was shaped by a very light rolling before spreading the bituminous material over it. The excess of bitumen was absorbed by a covering of sufficient fine white sand from near-by pits, and the road was finished by thorough rolling.

Frequent rains and showers during the work considerably delayed its progress and produced surface conditions which prevented the best results being obtained. It is clearly demonstrated that the greatest difficulty to be overcome in any future large-scale construction of bituminous coralline-rock roads is the harmful effect of rains on the prepared surface before the application of the bitumen. The high cementing power of the rock causes it to bind strongly when wet, unless the dust is entirely removed in the screening. The surface is thus rendered more or less impervious, and the treatment becomes in effect only a surface treatment. This difficulty may be met by performing such work in the dry season of the year, or by keeping at all times the prepared surface work and the bituminous application well together.

The equipment was the same as that used at Miami, consisting of a 10-ton gasoline roller, scarifier, grader, two 1-barrel heating kettles, and hand-pouring pots. Analyses of the bituminous materials used are given in the tables following.

TABLE 1.—*Analyses of asphaltic petroleums used in experiments at Lemon City, Fla.*

	Light.	Heavy.
	Experiment 2.	Experiments 1, 3.
Specific gravity 25°/25° C	0.960	0.992
Flash point.....°C.....	42	105
Burning point.....°C.....	67	145
Viscosity, Engler, specific.....	¹ 152.4	² 9.0
Loss, 5 hours at 163° C., 20 grams.....per cent..	27.53	16.33
Float test on residue, 50° C. (time).....	³ 2' 19"	² 40"
Percentage of total bitumen insoluble in 86° B. naphtha.....	10.40	10.83
Fixed carbon.....per cent..	5.01	5.82
Soluble in CS ₂ (total bitumen).....do.....	99.94	99.94
Organic matter insoluble.....do.....	.06	.04
Inorganic matter insoluble.....do.....	.00	.02
Total.....do.....	100.00	100.00

¹ At 25° C., 50 c.c.² At 100° C., 100 c.c.³ Soft, sticky, with slight flow.TABLE 2.—*Analysis of water-gas tar preparation used in experiments at Lemon City, Fla.*

	No. 1.		No. 2.	
	1.084 ¹ 13.3 1.54		1.120 ² 24.5 1.75	
Specific gravity 25 °/25°C				
Viscosity, Engler, 100 c.c., specific.....				
Free carbon.....per cent..				
	By vol- ume.	By weight.	By vol- ume.	By weight.
Distillation:				
Water.....per cent..	0.0	0.0	0.0	0.0
First light oils to 110° C.....do.....	³ 7	.5	³ 1.0	.6
Second light oils (110°-170° C.).....do.....	⁴ 1.1	.8	³ 8	.5
Heavy oils (170°-270° C.).....do.....	³ 34.6	31.1	³ 20.4	17.5
Heavy oils (270°-315° C.).....do.....	⁶ 14.1	12.5	⁶ 13.4	11.7
Pitch residue.....do.....	⁷ 49.5	55.0	⁸ 64.4	69.6
Total.....do.....	100.0	99.9	100.0	99.9

¹ At 25° C.² At 50° C.³ Clear.⁴ Cloudy.⁵ Clear, showed 15.0 per cent insoluble in dimethyl sulphate.⁶ Clear, showed 12.5 per cent insoluble in dimethyl sulphate.⁷ Hard, glossy. A 315°-350° C. fraction showed 17.5 per cent, and a 350°-375° C. fraction showed 12.5 per cent insoluble in dimethyl sulphate.⁸ Hard, glossy. A 315°-350° C. fraction showed 11.25 per cent, and a 350°-375° C. fraction showed 10 per cent insoluble in dimethyl sulphate.

EXPERIMENT NO. 1 (HEAVY OIL—PENETRATION METHOD).

Location: Station 0+00 to station 0+35.8=35.8 feet.

Area: 71.6 square yards.

Method.—It was attempted to produce a surface similar to that of experiment No. 6 at Miami, but with a heavier application of bituminous material. The conditions were adverse in the uneven texture of the surface caused by crushing under the roller, as mentioned above, and in the low temperature at which the bitumen had to be applied on account of its tendency to foam when heated. The application, though made evenly, puddled badly and produced, after the spreading of the sand, a rough mat. The bitumen was applied at an average rate of 1.26 gallons per square yard, and allowed to stand for about four hours, when it was covered with sand and rolled. This treatment, in general, appeared to be a failure.

EXPERIMENT No. 2 (LIGHT OIL—PENETRATION METHOD).

Location: Station 0+35.8 to station 0+58.1=22.3 feet.

Area: 44.6 square yards.

Method.—This section was intended to be a part of experiment No. 1, but owing to the destruction of the barrel markings during storage, a kettle of the light oil was heated by mistake and applied here at an average rate of 1.12 gallons per square yard. It was entirely absorbed during a half hour's standing, after which it was covered with sand and rolled.

EXPERIMENT No. 3 (HEAVY OIL—PENETRATION METHOD).

Location: Station 0+58.1 to station 1+65.9=107.8 feet.

Area: 215.6 square yards.

Method.—The apparent failure of experiment No. 1 necessitated a return to substantially the same method as was used in experiment No. 6 at Miami, although the poor working conditions did not promise equal success. The application of hot bitumen was reduced to an average rate of 0.89 gallon per square yard. From station 0+58.1 to station 1+39.0 the actual rate of application was 1.01 gallons per square yard. From station 1+39.0 to station 1+65.9 rains during the previous night had so bound the surface that the rate of application had to be reduced to 0.54 gallon per square yard, and little more than a surface treatment was obtained. The sand was applied and rolled as usual.

EXPERIMENT No. 4 (WATER-GAS TAR PREPARATIONS—SURFACE TREATMENT).

Location: Station 1+65.9 to station 1+95.4=29.5 feet.

Area: 59 square yards.

Method.—Owing to the postponement of the work from January 13 to 29, this section of the road had become completely water bound by rains and heavy traffic. The surface was thoroughly swept with rattan brooms, and water-gas tar preparation No. 1 applied without heating at a rate of 0.25 gallon per square yard and allowed to stand for 24 hours. Water-gas tar preparation No. 2 was then applied at the rate of 0.42 gallon per square yard and allowed to stand for about four hours. By that time it appeared to have reached its maximum penetration and was covered with sand and rolled. By the use of the light tar preparation applied directly to the surface of the rock and followed by the heavier product, it was hoped to secure greater adherence of the bituminous surface than had previously been obtained in strict surface treatment, and at the same time build up a comparatively thick wearing coat.

EXPERIMENT No. 5 (WATER-GAS TAR PREPARATION—PENETRATION METHOD).

Location: Station 1+95.4 to station 3+34.4=139 feet.

Area: 278 square yards.

Method.—The screened-rock course was constructed as usual, but by rescreening the rock the proportion of fine material was consider-

ably reduced. Conditions were generally better than in the other experiments of the series. The bitumen (water-gas tar preparation No. 2) was heated to an average temperature of 90° C., and applied at an average rate of 1.08 gallons per square yard, covered with sand, and rolled.

EXPERIMENT NO. 6 (CALCIUM CHLORIDE).

In connection with the foregoing series of bituminous experiments, a section of ordinary coralline-rock surface was treated with an application of calcium chloride, which is a hygroscopic salt obtained as a by-product in the manufacture of soda by the Solvay process. No record of the cost of this work was obtained.

The coralline-rock road is at its best when slightly wet or moist, and its rapid wear occurs when dry. It was hoped, therefore, that the application of a hygroscopic salt in this area bordering on the ocean would have the effect of keeping the surface damp, thus securing a serviceable and lasting condition.

Seven drums of calcium chloride, each weighing 350 pounds net, were furnished by the manufacturer. Five of these drums were used, the remaining two being reserved for a second application to the center of the roadway when necessary. The section which was treated on January 28, 1914, lies immediately north of experiment No. 1 and is 590 feet long and 18 feet wide, containing an area of 1,175 square yards. The rate of application was 1.49 pounds per square yard, heavy in the center and light on the extreme sides. The material came from the drums in a lumpy condition and was difficult to spread evenly. After several weeks of wear the surface was damp at all times, but pitted to some extent, showing bare rock in spots.

SUMMARY OF EXPERIMENTS AT LEMON CITY, FLA.

When inspected, on January 16, 1915, none of the experiments on which bituminous materials were used showed any decided evidence of failure. No. 1 appeared to be in slightly better condition than No. 3, on which the same heated oil had been used. It was fairly smooth, had a good cross section, and the bitumen still possessed life.

Experiment No. 2, where the light oil was used, was in good condition, but the bitumen had a brownish, dead appearance, and the individual rock particles showed throughout the section.

Experiment No. 4, which received the double surface treatment, showed a fine-grained mosaic surface with a few incipient potholes. It had not worn appreciably below the adjacent section.

Experiment No. 5 had a perfect mosaic surface, with slight indentations around the individual particles of stone. The bitumen had become quite hard, and the section should be given a light surface treatment at an early date. One depression was noted in this experiment, on the west side, at the joint about 55 feet from the south end.

The materials and cost data for these experiments are shown in the following table:

TABLE 3.—*Materials and cost data for experiments at Lemon City, Fla., 1914.*

Ex- peri- ment No.	Materials.	Description.		Quantities of materials per square yard.			Cost per square yard (cents).									
		Method.	Length of section (feet).	Area of section (square yards).	New rock (cubic yards).	Bitu- men (gallons).	Sand (cubic yards).	Pre- paring sub- grade.	Shoul- ders.	New rock in place.	Bitu- men. ²	Haul- ing bitu- men.	Sand.	Heat- ing and apply- ing bitu- men.	Rolling and finish- ing.	Total cost.
1	Heavy oil.....	Penetration.....	35.8	71.6	0.103	1.26	0.014	0.10	2.25	25.86	16.88	2.40	3.25	2.60	2.90	56.24
2	Light oil.....	do.....	22.3	44.6	.103	1.12	.014	.10	2.25	25.86	12.77	2.10	3.25	2.30	2.90	51.53
3	Heavy oil.....	do.....	107.3	215.6	.103	.89	.014	.10	2.25	25.86	11.93	1.70	3.25	1.90	2.90	49.89
4	Water-gas tar prepara- tion.....	Surface treatment.	29.5	59.0	.103	1.67	.014	.10	2.25	25.86	7.84	1.30	3.25	1.40	2.90	44.90
5	do.....	Penetration.....	139.0	278.0	.103	1.08	.014	.10	2.25	25.86	12.66	2.00	3.25	2.20	2.90	51.22

¹ Includes both applications.

² Bitumen cost based on quotations for tank-car lots.

EXPERIMENTS AT WEST PALM BEACH, FLA.

OIL, TAR, OIL-ASPHALT, CORALLINE ROCK.

These experiments, located on the Miami-Quebec highway, about 2 miles south of West Palm Beach, were constructed in April and May, 1914, by Palm Beach County, under the direction of the Office of Public Roads. The purpose was to develop a more economical and durable road surface than is obtainable by the use of coralline rock under ordinary methods of construction.

There are in this county about 150 miles of hard-surface roads. The material used exclusively for this surfacing is a soft, oölitic limestone known as coralline rock, or locally as simply "rock." It is obtained from two pits in Dade County, which borders Palm Beach County on the south. One of these pits, located at Fort Lauderdale, furnishes a coralline rock which is softer than the average and contains a considerable proportion of sand. For ordinary construction, it has given apparently satisfactory results. The rock quarried from the other pit, located at Ojus, is blasted and excavated from under water. It is comparatively hard and contains a relatively small amount of fine material. It was therefore chosen as the more suitable of the two for bituminous construction, and used in the experiments.

The experience gained from the construction of the experiments at Miami¹ and from their inspection after long usage by traffic showed conclusively that the best method of treatment involved the use of rock from which the finer particles had been removed to provide for uniform penetration of the bitumen. The experiments at West Palm Beach were therefore all constructed on this basic principle. The general method of construction preparatory to the application of the bitumen was, in brief, as follows:

The preparation of a thoroughly compacted subgrade parallel to the finished surface and composed of the rock originally in the roadbed; upon this, a course of screened rock with a uniform loose depth of 3 inches, lightly compacted to allow a maximum penetration of bituminous material.

The screened rock used was produced at great disadvantage and consequently high cost. Furthermore, in addition to screening out the material below one-half inch in size, it would have been desirable, if practicable, to screen out all above 2½ inches. These larger sizes had to be picked out by hand by the rakeman on the screen and by the spreaders on the road. In any large-scale future work, a small crushing plant, elevator, revolving screens, and bins should be installed, preferably at the quarry. All rock was spread by shoveling back from piles dumped a little in advance of the work.

¹ Bulletin of the U. S. Department of Agriculture No. 105.

The sand used, from which roots and grass were removed by the use of a $\frac{3}{8}$ -inch screen, was a clean, white silica obtained at the roadside.

Dustless screenings, so-called, were obtained by rescreening on a $\frac{1}{4}$ -inch screen all rock that had passed the $\frac{1}{2}$ -inch screen. All material passing the $\frac{1}{4}$ -inch mesh was classed as "extra fines." About 33 per cent of the rock passed the $\frac{1}{2}$ -inch screen, of which one-half was recovered on the $\frac{1}{4}$ -inch screen. There was no appreciable change in volume between the pit run and the screened rock above one-half inch.

It was found necessary to extend the width of the subgrade from 12 feet to 15 feet on account of the thin depth of the original rock outside the former width. This was done by trenching the sides and backfilling with sufficient rock to give the required grade. About 15 per cent of the total cost of the work was expended in this manner.

EXPERIMENT NO. 1 (RESIDUAL ASPHALTIC PETROLEUM—PENETRATION METHOD).

Location: Station 0+00 to station 1+02=102 feet.

Area: 170 square yards.

TABLE 4.—*Analysis of residual asphaltic petroleum.*

Specific gravity 25°/25° C.....	0.989
Flash point.....°C.....	130
Burning point.....°C.....	155
Viscosity, Engler, 100 c. c. at 100° C., specific.....	9.8
Float test at 32° C. (time).....	44"
Float test at 50° C. (time).....	27"
Loss, 5 hours at 163° C., 20 grams.....per cent..	13.74
Float test on residue at 32° C. (time).....	7' 49"
Float test on residue at 50° C. (time).....	2' 0"
Percentage of total bitumen insoluble in 86° B. naphtha.....	10.05
Fixed carbon.....per cent..	4.68
Soluble in CS ₂ (total bitumen).....do....	99.92
Organic matter insoluble.....do....	.05
Inorganic matter insoluble.....do....	.03
Total.....	100.00

Method.—The screened-rock course was lightly rolled to bring the surface to a smooth cross section and leave an open surface which would allow deep penetration of the bitumen. The rate of application for the penetration course was 1.76 gallons per square yard, at an average temperature of 95° C. No excess of bitumen remained on the surface, which was then covered with sand and thoroughly rolled. Before applying the seal coat all free sand was swept from the surface with rattan brooms. The rate of application of the seal coat was 0.56 gallon per square yard. A top dressing of sand was applied and the surface thoroughly rolled.

A. From stations, 0+00 to 0+50, the seal-coat application was allowed to stand two hours before sanding.

B. From stations, 0 + 50 to 1 + 02, approaching rains necessitated the sanding of the seal coat immediately after application. This caused a marked difference in the resulting surface condition of portions A and B of the experiment. The mat on the latter contained an excess of bitumen, and more sand had to be added from time to time until a thick, mushy top was formed. About a month after construction this mat was removed, heated, and respread to a thickness of about one-quarter of an inch.

The bituminous material used in this experiment was found to contain a small percentage of water, probably due to seepage through the barrels during transit. In heating, when the temperature reached the boiling point of water, the material foamed so excessively as to cause overflowing from the kettles. It was necessary, therefore, to apply the oil at a temperature of about 95° C., which was lower than desirable for best results and caused the rate of application to be greater than necessary. It was also found that the top voids, although assisting in securing excellent penetration, were too large to assure good results when filled with sand dressing.

EXPERIMENT NO. 2 (REFINED COAL TAR—PENETRATION METHOD).

Location: Station 1 + 02 to station 1 + 94 = 92 feet.

Area: 153.3 square yards.

TABLE 5.—*Analyses of refined coal tars.*

	Lot No. 1.		Lot No. 2.	
Specific gravity 25°/25° C.....	1.288		1.282	
Float test at 50° C. (time).....	4' 18"		3' 33"	
Free carbon.....per cent..	29.61		28.30	
	By volume.	By weight.	By volume.	By weight.
Distillation:				
Water.....per cent..	0.0	0.0	0.0	0.0
First light oils to 110° C.....do..	1.1	.1	2.4	.2
Second light oils (110°-170° C.).....do..	2.6	.4	2.3	.4
Heavy oils (170°-270° C.).....do..	33.8	3.0	34.4	3.4
Heavy oils (270°-315° C.).....do..	411.5	9.4	511.4	9.0
Pitch residue.....do..	684.0	87.1	683.5	86.8
Total.....	100.0	100.0	100.0	99.8

¹ One-half solid.
² Solid.

³ Cloudy.
⁴ One-eighth solid.

⁵ One-fifth solid.
⁶ Hard, dull, brittle.

Method.—The rock course was rolled more heavily to reduce the voids below the percentage obtaining in experiment No. 1. The heavy refined tar, designated as lot No. 1, was then applied at the rate of 0.98 gallon per square yard. The average temperature of the tar was 175° C. The rock was dry and hot from the sun, the tar

flowed readily and, after standing a few minutes, entirely penetrated into the rock course. Sand was then applied and swept into the voids. The sand dressing, however, while filling the voids, did not incorporate with the bitumen, but remained for the most part dry and loose. The individual tar-coated rock particles were left projecting and unprotected and would have worn away rapidly under traffic. All free sand was therefore swept from the surface, and a light coal tar was applied cold at the rate of 0.33 gallon per square yard and allowed to stand for about four hours until completely absorbed. The surface was then covered with sand and thoroughly rolled. The sample of the light tar was lost in shipment, and consequently no analysis is given.

EXPERIMENT NO. 3 (REFINED COAL TAR—PENETRATION METHOD).

Location: Station 1+94 to station 3+68.8=174.8 feet.

Area: 291.5 square yards.

Material: Refined coal tars, analyses of which are given in Table 5.

Method.—The general nature of this experiment is the same as that of the preceding, except for the omission of a second application of bituminous material and the use of dustless screenings instead of sand. From station 3+25 to the end of the next experiment heavy rains had so bonded the rock surface that it had to be harrowed, regraded, and rolled in order to provide for suitable penetration. The smoothness of the original cross section could not be restored, and the surface of this portion of the road remains slightly irregular. The application of bituminous material was made at the rate of 1.20 gallons per square yard, and was immediately covered with dustless screenings, filling the voids and thinly covering the surface, which was then thoroughly rolled. The screenings crushed somewhat under the roller, but seemed to absorb the bituminous material and form a firm, rigid surface.

Tar of lot No. 1 was used from station 1+94 to station 2+76. From the latter point to the end of the section material from a second shipment, designated in Table 5 as lot No. 2, was used. This material did not flow and penetrate as satisfactorily as lot No. 1, even when heated to 185° C.

EXPERIMENT NO. 4 (RESIDUAL ASPHALTIC PETROLEUM—PENETRATION METHOD).

Location: Station 3+68.8 to station 5+84=215.2 feet.

Area: 358.6 square yards.

TABLE 6.—*Analysis of residual asphaltic petroleum.*

Specific gravity, 25°/25° C.....	0.980
Flash point.....°C..	125
Burning point.....°C..	143
Viscosity, Engler, 100 c. c. at 100° C., specific.....	5.5

Float test at 32° C. (time)	22"
Float test at 50° C. (time)	14"
Loss, 5 hours at 163° C., 20 grams	per cent.. 16.82
Float test on residue at 32° C. (time)	6' 30"
Float test on residue at 50° C. (time)	1' 46"
Percentage of total bitumen insoluble in 86° B. naphtha	9.37
Fixed carbon	per cent.. 4.64
Soluble in CS ₂ (total bitumen)	do.... 99.87
Organic matter insoluble	do.... .05
Inorganic matter insoluble	do.... .08
Total	do.... 100.00

Method.—The rock course was rolled until firm, after which dustless screenings were scattered lightly over the rock surface, partly filling the larger voids. The rate of application of the bitumen was 1.39 gallons per square yard at an average temperature of 105° C. The bitumen flowed readily and penetrated completely when allowed to stand for a sufficient time. Frequent rains during the treatment of this section handicapped the performance of the work and at times necessitated sanding immediately after the application of the bitumen.

A. From stations 3 + 68.8 to 5 + 15.5, sand was used as a top dressing. This section bled profusely and unevenly for about two weeks after construction, forming a sand mat of uneven thickness. In those areas where there was no bleeding the surface had a light brown color and the bitumen seemed to have become somewhat absorbed in the rock itself. Traffic was permitted the use of this portion of the experiment immediately after construction.

B. From stations 5 + 15.5 to 5 + 84, dustless screenings were used as top dressing and there was no bleeding over this area. Traffic did not use this section until three weeks after construction.

EXPERIMENT NO. 5 (OIL-ASPHALT—PENETRATION METHOD).

Location: Station 5 + 84 to station 6 + 32 = 48 feet.

Area: 80 square yards.

TABLE 7.—*Analysis of oil-asphalt.*

Specific gravity, 25°/25° C.	1.008
Melting point	°C.. 58
Penetration, 25° C., 100 grams, 5 seconds	m. m.. 10.2
Loss, 5 hours at 163° C., 20 grams	per cent.. .44
Penetration of residue, as above	7.9
Percentage of total bitumen insoluble in 86° B. naphtha	23.97
Fixed carbon	per cent.. 11.06
Soluble in CS ₂ (total bitumen)	do.... 99.86
Organic matter insoluble	do.... .10
Inorganic matter insoluble	do.... .04
Total	do.... 100.00

Method.—The work on the experimental road was discontinued from April 16 to May 18, owing to delay in the arrival of the oil asphalt. During this time heavy rains had rendered the prepared rock surface unfit for penetration work, and it was therefore harrowed, regraded, and rolled to proper condition from station 5+84 to station 8+60. The larger voids were partly filled with dustless screenings. The rate of application of bituminous material was 1.75 gallons per square yard, and the average temperature was 175° C. The penetration was not good, owing to the rapid congealing of the oil asphalt on a dense surface of this type. The top dressing of dustless screenings was immediately applied in sufficient quantity to fill the voids and thinly cover the surface, which was then thoroughly rolled.

EXPERIMENT NO. 6 (OIL ASPHALT—PENETRATION METHOD).

Location: Station 6+32 to station 7+17=85 feet.

Area: 141.6 square yards.

Material: Oil asphalt, analysis of which is shown in Table 7.

Method.—The rock course was compacted with a rather heavy rolling. An application of oil asphalt was made at the rate of 1.52 gallons per square yard and at an average temperature of 185° C. This was immediately covered with sand. As in experiment No. 2, the sand did not become incorporated with the bitumen, but remained to a large extent dry and loose. All free sand was swept entirely off the road, and a sand-asphalt mixture was spread upon the penetration course. This was composed of 1 cubic foot of roadside sand to 1 gallon of oil asphalt, both at a temperature of 175° C. The mixture filled the interstices and formed a wearing surface about one-quarter of an inch thick above the topmost particles of the rock. It bonded with the lower course both by irregularities in the latter and by reason of the melting of the first bituminous coat through contact with the hot mixture.

EXPERIMENT NO. 7 (WATER-BOUND MACADAM).

Location: Station 7+17 to station 8+60=143 feet.

Area: 238.3 square yards.

Method.—As in the previous experiments, the subgrade was prepared and compacted parallel to the cross section of the finished road, and a course of screened rock spread to a uniform depth of 3 inches. This was heavily rolled until there was no visible yielding under the roller. No material was available from the first screening through a ½-inch screen. Dustless screenings and dust were therefore mixed in equal parts and spread over the surface, after which the roadway was flushed with water and thoroughly rolled.

One purpose of this experiment was to provide a basis of comparison between the various bituminous treatments and a well-constructed coralline-rock road. Another and more important one was to demonstrate, if possible, that the principal defect in the existing roads, the rapid development of an uneven surface, could be overcome by proper methods of construction. By the method here used a surface of uniform strength is secured by reason of the uniform strength of the subgrade and the uniform depth and consistency of the screened-rock course. Such uniformity can be obtained in no other way, apparently, than by screening the rock and following the general method of construction used in this experiment.

In the cost data, which follow, the cost of bituminous materials was taken from bid prices for carload lots.

TABLE No. 8.—*Materials and cost data for experiments at West Palm Beach, Fla., 1914.*

Experiment No.	Materials.	Description.		Quantities of materials per square yard.						Cost per square yard (cents).										Total
		Length of section (feet).	Area of section (square yards).	New rock (cubic yards).	Bituminous material, first application (gallons).	Bituminous material, second application (gallons).	Rock screenings (cubic yards).	Sand (cubic yards).	Extending width.	Preparing subgrade.	New rock in place.	Bituminous material.	Sand or screenings.	Spreading sand or screenings.	Heating, mixing, and applying bituminous-sand mat.	Sprinkling.	Rolling and finishing.	Miscellaneous.	General charges. ¹	
1	Residual asphaltic petroleum.....	102.0	170.0	0.083	1.76	0.56	.....	0.021	8.52	4.57	23.94	27.84	0.54	0.50	.....	.....	1.46	3.50	3.32	74.19
2	Refined coal tars.....	92.0	153.3	0.083	1.95	.33	.....	.021	8.52	4.57	23.94	11.95	0.54	.50	.....	.....	1.46	3.50	3.32	58.32
3	Refined coal tar.....	174.8	291.5	0.083	1.20	.....	0.014	.....	8.52	4.57	23.94	11.40	2.25	.30	.....	.....	1.46	3.50	3.32	58.26
4	Residual asphaltic petroleum.....	215.2	358.6	0.083	1.39	.....	.004	.010	8.52	4.57	23.94	16.68	30	.30	.....	.....	1.46	3.50	3.32	63.19
5	Oil-asphalt.....	48.0	80.0	0.083	1.75	.....	.014	.....	8.52	4.57	23.94	19.69	2.25	.30	.....	.....	1.46	3.50	3.32	67.55
6	do.....	85.0	141.6	0.083	1.52	.30	.....	.021	8.52	4.57	23.94	20.47	2.54	.50	.....	.....	1.46	3.50	3.32	76.28
7	Water-bound macadam.....	143.0	238.3	0.083	.....	.....	.028	.....	8.52	4.57	23.94	.....	4.51	.60	.....	0.60	1.46	3.50	3.32	51.02

¹ Includes rental of kettles, supplies, hauling, oil, etc.

SUMMARY OF EXPERIMENTS AT WEST PALM BEACH, FLA.

These experiments were carefully inspected on January 20, 1915, and their general condition reported upon as follows:

Experiment No. 1.—The surface of this experiment throughout is in uniformly good condition. The bitumen is still lively and possesses, to a certain extent, its original characteristic odor. The flow of the excessive bitumen is noticeable here and there along the side of the road, but there are no waves or irregularities that would be apparent to traffic.

Experiment No. 2.—The general character of this experiment is about the same as that of No. 1, except for its darker color and the fact that the bituminous material has become very hard and brittle.

Experiment No. 3.—The tar used in this experiment has become hard and friable. The excess present in the original construction, as well as the top dressing of fine rock, has disappeared. The surface has worn almost uniformly to a perfect mosaic or terrazzo appearance, and the large particles of soft rock now exposed are wearing very rapidly. A surface treatment will therefore be applied before any serious wear occurs.

Experiment No. 4.—This section, while it is in good condition and free from any wearing defects, presents a varied appearance. Where sand was used there are places which bear a close resemblance to experiment No. 1, while other areas show a mosaic appearance due to the wearing of the rock in the wearing course. These differences are undoubtedly due to the varied weather conditions under which the experiment was constructed.

Where rock screenings were used the surface is much lighter and somewhat mottled, and evidently more susceptible to wear than the sanded surface.

Experiment No. 5.—This experiment has a mottled appearance due to the fact that the bitumen has bled to the surface and formed a mat over some areas, while the rock is exposed to wear in others. The bituminous material is still lively.

Experiment No. 6.—This experiment is reported as having been somewhat soft and sticky during the summer of 1914, but at the time of this inspection it was in excellent condition and presented a smooth surface true to the original cross section.

Experiment No. 7.—This experiment offers an excellent example of the relative wear of water-bound coralline rock as compared with the bituminous-bound. The surface is smooth, unbroken, and true to cross section, but measurements made where it joins the adjacent bituminous-bound section indicate that the water-bound macadam has worn down about seven-eighths of an inch below the adjacent bituminous-bound section.

The following table shows the results of a traffic census taken between 6 in the morning and 12 midnight on three successive days in January, 1915.

TABLE 9.—*Volume and character of traffic over experiments at West Palm Beach, Fla., on three successive days in January, 1915.*

Vehicles.	Saturday, Jan. 23. ¹		Sunday, Jan. 24. ²		Monday, Jan. 25. ³		Average per day.
	North-bound.	South-bound.	North-bound.	South-bound.	North-bound.	South-bound.	
Loaded 1-horse wagons	7	6	2	1	3	7	8.7
Unloaded 1-horse wagons	4	4	1	3	7	7	8.7
Loaded 2-horse wagons	5	2	1	1	5	0	4.7
Unloaded 2-horse wagons	4	2	0	0	1	4	3.7
1-horse pleasure vehicles	3	4	1	2	2	2	4.7
Motor cycles	15	19	12	10	16	15	29.0
Motor runabouts	11	14	0	3	8	14	13.3
Motor touring cars	127	114	82	84	97	102	202.0
Loaded motor trucks	1	2	0	0	1	3	2.3
Unloaded motor trucks	1	1	1	1	3	0	2.3
Bicycles	101	141	49	65	118	130	201.3

¹ Heavy rain morning and evening; showers all day.

² Heavy rain 6 to 7 a. m., 12 to 6 p. m.; showers balance of day.

³ Heavy rain 10 a. m. to 1 p. m.; showers balance of day.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT MIAMI, FLA., 1913.

OIL-CORALLINE ROCK.

The original report of these experiments will be found in U. S. Department of Agriculture Bulletin No. 105. When inspected and repaired on January 29, 1914, the surface treatment in experiments Nos. 1 and 2 had worn so badly that repairs were out of the question. It had broken through in a number of places, exposing the soft underlying rock to excessive wear, and this finally resulted in such a rough and objectionable surface that both sections were later scarified, regraded, and rolled without further treatment. The remaining experimental sections were repaired where necessary by patching all holes and breaks in the surface in the following manner:

The surface was cut away around the affected areas to form holes about 4 inches deep, with straight, sharp edges. These were filled with a thorough mixture of pit-run rock and the light-oil product, with care to use only sufficient oil to coat all the particles. The mixture was tamped in place in layers about 1 inch thick. The following table shows the extent and cost of these repairs:

TABLE 10.—*Cost of repairs to experiments at Miami, Fla.*

Experiment No.	Area of patches (square feet).	Cost.	Cost per square yard.
3.....	0	\$0.00	\$0.000
4.....	3	.89	.002
5.....	24	7.17	.013
6.....	0	.00	.000

The following report covers the condition of the existing experiments on January 16, 1915:

EXPERIMENT No. 3 (PENETRATION METHOD—HOT, HEAVY OIL).

This experiment remains in fairly good condition, although it has worn to a somewhat rough and uneven cross section. No breaks have occurred, however, and only one worn depression was noted.

EXPERIMENT No. 4 (PENETRATION METHOD—COLD, LIGHT OIL).

This experiment continues in fair condition, although it does not present as good an appearance as No. 3. A group of small worn places were noted just north of the middle of the section.

EXPERIMENT No. 5 (PENETRATION METHOD—HOT, HEAVY OIL).

This is decidedly the poorest of the remaining sections, and apparently demonstrates the lack of economy in reducing the wearing course of rock to less than $2\frac{1}{2}$ inches of uncompacted material. Seventeen worn depressions, ranging from one-half square foot to 2 square feet in area were distributed throughout the section, and it was apparent that they had been brought to grade by filling with coralline rock. These will be patched with bituminous material and rock.

EXPERIMENT No. 6 (PENETRATION METHOD—HOT, HEAVY OIL).

This experiment continues in excellent condition after having been under rather heavy traffic for over 18 months, and is a successful demonstration of what can be accomplished in this form of construction. The bitumen has flowed in a couple of places and is still lively, but the cross section is well preserved, and there is no evidence of excessive wear.

**SUPPLEMENTARY REPORT OF EXPERIMENTS ON ROCKVILLE PIKE,
MARYLAND, 1913.**

The original report of these experiments was given in U. S. Department of Agriculture Bulletin No. 105, and the following information covers their history to and including an inspection on February 9, 1915.

EXPERIMENT No. 1 (REFINED COAL TAR—HOT APPLICATION).

This experiment has shown somewhat marked fraying along the edges, and a very noticeable deterioration of a strip along one edge for about 400 feet where trees overhang the road. The underlying macadam is fast becoming exposed over fairly large areas, and at the time of inspection it appeared probable that the restoration of the mat will be necessary early in the spring of 1915. One single-track trolley

crossing has somewhat increased the surface-repair costs. No repairs, however, have been large in size. The experiment is in generally good condition except for the uniform wear, and it is free from holes or weak spots.

The part of this experiment in Bradley Lane is suffering severely by reason of the very heavy traffic in both directions. The frequent passing compels practically every vehicle to run off the metal at some point, and the continual wear at the edges has reduced the effective width and caused damage that can not be satisfactorily repaired short of reconstruction. This is an obvious case of the traffic being too heavy for a single-line road.

EXPERIMENT NO. 2 (REFINED WATER-GAS TAR—COLD APPLICATION).

In the early summer of 1914 the surface of this experiment began to fail so rapidly through numerous breaks in the mat that it became practically impossible to prevent total failure by means of patrol maintenance. The failure seemed more pronounced over that portion of the experiment where gravel had been used, and this is attributed to the fact that the gravel was coarser than it should have been.

Therefore, between June 29 and July 3 a second treatment was applied. Refined water-gas tar purchased under the specification for the original treatment was used, and the application was made by means of an automobile pressure distributor. The tar was brought directly from the stills of the manufacturer and applied at a temperature of 150° to 175° F. Clean trap-rock chips and $\frac{3}{8}$ -inch gravel were used as a covering material, each over the same parts of the experiment where it had been originally used. The characteristics of the bituminous material are given in the following table, and the cost data will be found at the end of this supplementary report.

TABLE 11.—*Analysis of refined water-gas tar.*

Specific gravity 25°/25° C.....	1.123
Viscosity, Engler, 50 c. c. at 50° C., specific.....	27.0
Free carbon.....	per cent.. 0.80
Distillation:	
	By volume. By weight.
Water.....	per cent.. 0.0 0.0
First light oils to 110° C.....	do... ¹ 1.1 .1
Second light oils (110°–170° C.).....	do... ¹ 6 .5
Heavy oils (170°–270° C.).....	do... ² 26.5 23.4
Heavy oils (270°–315° C.).....	do... ² 13.8 12.5
Pitch residue.....	do... ³ 59.0 63.4
Total.....	do... 100.0 99.9

This surface is now fully as good, if not better, than at the time of original construction. There are two sections of surface, near Norwood trolley station and south of Edgewood station, where the

¹ Trace solid.

² One-fourth solid.

³ Fairly hard and glossy.

original construction left the road flat and inadequately drained. These are now showing the strain of more or less continued dampness from underneath. The gravel section of this experiment has a markedly better appearance than the trap section.

The surface of experiment No. 2 in Bradley Lane is in fairly good condition and free from bad holes or depressions.

EXPERIMENT NO. 3 (ASPHALTIC PETROLEUM—COLD APPLICATION).

The surface of this experiment also began to fail rapidly during the summer of 1914, and the failure seemed most pronounced at first on the section where rather coarse gravel had been used for a covering material. Moreover, during the winter of 1913-14, not only was the surface cut through because of culvert repairs, but several rather large areas heaved as a result of frost action. This latter damage was due to the partial burning out of some of the surfacing bitumen by bonfires set along the outer edge of the road. In a few places along the sides of the road the surface mat had cracked to some extent.

A new treatment was therefore applied between September 23 and 27, in which the same grade and character of oil as that originally applied was used. The application was made by permitting the oil to run from the bung of the barrel and sweeping it over the surface with rattan push brooms. From station 135+00 to station 144+00, where the original surface was still fairly smooth and intact, the application was at the rate of 0.13 gallon per square yard, while over the remainder of the experiment it was at the rate of 0.18 gallon per square yard. The average was 0.176 gallon per square yard. The application was immediately covered with clean torpedo sand.

Table No. 12 shows the characteristics of the bituminous material used, and the cost data will be found at the end of this supplementary report.

TABLE 12.—*Analysis of asphaltic petroleum.*

Specific gravity 25°/25° C.	0.932
Flash point. °C.	35
Burning point. °C.	70
Viscosity, Engler, 50 c. c. at 25° C., specific.	61.9
Loss, 5 hours at 163° C., 20 grams. per cent..	22.94
Float test of residue at 32° C. (time).	5' 53"
Float test of residue at 50° C. (time).	1' 22"
Percentage of total bitumen insoluble in 86° B. naphtha.	13.67
Fixed carbon. per cent..	7.62
Soluble in CS ₂ (total bitumen). do.	99.90
Organic matter insoluble. do.	.10
Inorganic matter insoluble. do.	.00
Total. do.	100.00

At the date of inspection this experiment was in essentially as good condition as at the time of construction. The surface was noticeably better on the gravel half of the section and had a corky feeling to the tread throughout. In wet weather the surface has become somewhat muddy, especially in the bottoms, and this action appears characteristic of all the experimental surfaces treated with petroleum products.

In deducing maintenance costs for this section, proper allowance has been made by excluding the cost of subsurface repairs not due to failure of the surface treatment.

EXPERIMENT NO. 4 (RESIDUAL ASPHALTIC PETROLEUM—HOT APPLICATION).

This experiment presented probably the best appearance of any of the original construction at the time of last inspection. During the winter of 1913-14 its surface remained practically intact, but in the winter of 1914-15 it cracked in a few places and became slightly muddy. The muddy condition rapidly disappears in dry weather and a smooth leathery surface results.

The surface has had about the same amount of attention as that of experiment No. 1, and will probably not require a general re-treatment during the coming season. This experiment, together with No. 5 and No. 6, all of which were given hot surface treatments, required considerable top-dressing during the first warm days of spring to stop further bleeding. The surface still has a few humps in spots where the distributor leaked at the time of spreading the bitumen. Many of these humps have been cut down with a mattock or hot shovel, but all are not yet entirely removed, because their tendency to bleed and consequent addition of top-dressing tend to build them up again. Three or four potholes were noted, and at one place on the east side of the road there appears to be a stripped track that has developed since the late fall of 1914. This may have been a long repair made at the time of construction after an automobile ran over the section before top-dressing was spread. Along this strip, some 500 or 600 feet in length, and between it and the edge of the surface the underlying macadam is generally bare, but is not raveling.

EXPERIMENT NO. 5 (RESIDUAL ASPHALTIC PETROLEUM—HOT APPLICATION).

The surface shows a tendency to crack in cold weather, and in wet weather works into a mud more readily than the surface of experiment No. 4. Like experiment No. 4, the surface is soon ironed into a smooth, leathery mat when dry weather permits. During the year the cost of surface work has been greater than on No. 1 or No. 4. It was also slightly higher than on No. 6. The hilltop at the north end of the experiment is better than elsewhere, probably on account of more thorough subdrainage. Any areas poorly drained are at once noticeable through this surface.

EXPERIMENT NO. 6. (WATER-GAS TAR PREPARATION—HOT APPLICATION).

This experiment bled rather freely in the spring and required considerable top-dressing and repairs, especially on the trap section. The surface does not become muddy, although dampness shows through along several areas where subdrainage is poor. Most of the repairs so far have been due to some little stripping of the bitumen that occurred early in the spring before top-dressing could be applied. Such repairs have, however, been few, and less bitumen has been required than on any of the other experiments.

EXPERIMENT NO. 7 (ASPHALTIC PETROLEUM—COLD APPLICATION).

The surface of this experiment worked into a rather objectionable muddy condition as soon as the winter of 1913-14 brought continued wet weather and frost. In the spring it ironed out and presented a very satisfactory appearance until about September. At this time numerous small weaknesses began to develop which, owing to cold weather, could not all be repaired before winter. Nevertheless, the surface has not become so muddy this winter (1914-15) as last, but the mud which is formed is in some spots a lighter brown color, indicating that the oil is losing its effect. This experiment is expected to require re-treatment at the earliest possible time in the spring, and may require considerable patching, as indicated by the rapidly increasing breaks in the surface during the late fall of 1914.

TABLE 13.—*Materials and cost data for renewal treatments of experiments Nos. 2 and 3 Rockville Pike, Maryland, 1914.*

	Experiment No. 2.		Experiment No. 3.
	Trap.	Gravel.	Torpedo sand.
Length.....feet..	4,330	3,050	7,400
Area.....square yards..	7,216.6	5,063.4	12,333
Bituminous material, per square yard.....gallons..	.294	.294	.176
Covering material, per square yard.....cubic yards..	.012	.012	.009
Cost (cents per square yard):			
Sweeping surface.....	(1)	(1)	0.048
Bituminous material.....	2.79	2.79	1.234
Applying bituminous material.....	(1)	(1)	.393
Covering material.....	4.39	2.52	1.994
Spreading covering material.....	.53	.53	.197
Total cost.....	7.71	5.84	3.866

¹ Automobile distributor used; sweeping and applying included in cost of material.

A traffic census on the Rockville Pike is taken every 13 days for a 24-hour period. A tabulation of the maximum and average of each class of traffic for the period between January 1, 1914, and January 1, 1915, is given in Table 14.

TABLE 14.—*Volume and character of traffic on Rockville Pike at its intersection with Bradley Lane.*

Vehicle.	Maximum.		Average.	
	North-bound.	South-bound.	North-bound.	South-bound.
Loaded 1-horse wagon	25	23	13	13
Unloaded 1-horse wagon	26	26	12	11
Loaded 2-horse wagon	31	71	13	27
Unloaded 2-horse wagon	59	14	20	6
Loaded 4-horse wagon	4	4	1	1
Unloaded 4-horse wagon	5	3	1	0
1-horse pleasure vehicle	22	24	12	14
2-horse pleasure vehicle	5	5	1	2
Rubber-tired horse vehicle	3	2	0	0
Saddle horse	18	19	5	5
Motor cycle	39	35	20	13
Excessively heavy vehicle	12	18	3	4
Motor runabout	98	91	42	42
Motor touring car	243	187	96	89
Loaded motor dray	24	38	12	16
Unloaded motor dray	29	12	7	5

The total cost of maintenance and cost to date of each experiment are shown in the following table:

TABLE 15.—*Maintenance cost of experiments on Rockville Pike, Maryland, to December 31, 1914.*

Ex- per- iment No.	Bituminous material.	Date com- pleted.	Length (feet).	Cost ¹ per square yard (cents).	Surface ² main- tenance per square yard (cents).	Total cost of surface per square yard to Dec. 31, 1914.	Surface main- tenance per mile for 1 year.	Total main- tenance per mile for 1 year.
1	Refined coal tar (hot)...	1913. Sept. 22	6,105	12.34	1.58	13.92	\$139.04	\$332.93
2	Refined water-gas tar (cold)	Sept. 24	7,380	9.55	7.56	17.11	665.28	739.11
3	Asphaltic petroleum (cold)	Sept. 30	7,400	9.05	6.00	15.05	528.00	576.26
4	Residual asphaltic pe- troleum (hot)	Oct. 15	7,100	11.28	1.61	12.89	141.68	215.18
5	Do	Nov. 21	6,775	11.30	2.00	13.30	176.00	237.37
6	Water-gas tar prepara- tion (hot)	Nov. 26	6,325	11.71	1.88	13.59	165.44	219.47
7	Asphaltic petroleum (cold)	Dec. 5	6,689	10.03	.71	10.74	62.48	106.82

¹ Average for trap and gravel.² To Dec. 31, 1914.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT WASHINGTON, D. C., 1912.

TAR PREPARATIONS AND OILS—SURFACE TREATMENT.

The original report of these experiments was published in Circular No. 99 of the Office of Public Roads, and the inspection report for the first year was given in U. S. Department of Agriculture Bulletin No. 105. The following report gives the extent of the repairs during 1914 and the condition of the experiments when inspected on March 11, 1915:

All four sections in the summer of 1914 showed considerable wear. The surface mat of section No. 1 apparently was becoming somewhat

brittle, especially along the sides of the road, although the treatment still remained generally intact. Section No. 2 had developed several holes of considerable area, but otherwise the surface was in excellent condition. Section No. 3 had several small holes, and the surface mat was largely worn off. The surface of section No. 4 was smooth and regular, but the large stones of the macadam were generally showing. The only repair necessary in this section was a water-bound patch approximately 6 square yards in area on the northwest side of the curve leading toward Twelfth Street, where there is practically no traffic.

In addition to this large patch, others of water-bound macadam were placed in sections 2 and 3. The total area of such patches was about 11 square yards.

The sections were then swept with hand brooms and given a surface treatment of the same type of bituminous material as that originally used, and covered with a fine torpedo sand. Some bituminous material had remained from the previous treatment, as follows: 130 gallons of residual petroleum for section No. 3, which was sufficient to treat the entire section, and 50 gallons of water-gas tar preparation, which was used on the south end of section No. 1.

Application of the bituminous material was accomplished by allowing it to run from the bungs of the barrels or drums directly upon the road and distributing it with push brooms. It was covered immediately with sand.

Analyses of additional materials purchased for this work are given in the following tables:

TABLE 15.—*Mechanical analysis of sand used in surface treatment at Washington, D. C., 1914.*

Retained on $\frac{1}{8}$ -inch screen.....	per cent..	11.8
Passing $\frac{1}{8}$ -inch screen, retained on 10-mesh sieve.....	do....	6.7
Passing 10-mesh sieve, retained on 20-mesh sieve.....	do....	17.9
Passing 20-mesh sieve, retained on 30-mesh sieve.....	do....	9.3
Passing 30-mesh sieve, retained on 40-mesh sieve.....	do....	12.3
Passing 40-mesh sieve, retained on 50-mesh sieve.....	do....	10.9
Passing 50-mesh sieve, retained on 80-mesh sieve.....	do....	20.4
Passing 80-mesh sieve, retained on 100-mesh sieve.....	do....	3.7
Passing 100-mesh sieve, retained on 200-mesh sieve.....	do....	3.7
Passing 200-mesh sieve.....	do....	3.3
Total.....	do....	100.0

TABLE 16.—*Analysis of water-gas tar preparation used on section No. 1.*

Specific gravity 25°/25° C.....	1.091
Viscosity, Engler, 100 c. c. at 50° C., specific.....	18.4
Free carbon.....	per cent.. 2.22

Distillation:		per cent.	By vol-	By
			ume.	weight.
Water	.....	per cent.	¹ 0.1	0.1
First light oils to 110° C.	.....	do.	¹ 6	.4
Second light oils (110°-170° C.)	.....	do.	¹ 1.1	.8
Heavy oils (170°-270° C.)	.....	do.	¹ 23.1	20.0
Heavy oils (270°-315° C.)	.....	do.	² 10.5	9.5
Pitch residue	.....	do.	³ 64.6	68.8
Total	.....	do.	100.0	99.6

TABLE 17.—*Analyses of asphaltic petroleum*s used on sections Nos. 2 and 4, Washington, D. C., 1914.

	Section No. 2.	Section No. 4.
Specific gravity 25°/25° C.	0.957	0.936
Flash point.....° C.	38	30
Burning point.....° C.	70	68
Viscosity, Engler, 50 c. c. at 25° C., specific.	104.5	87.5
Loss, 5 hours at 163° C., 20 grams.....per cent.	26.66	24.01
Float test on residue at 32° C. (time).....	5' 14"	6' 22"
Float test on residue at 50° C. (time).....	1' 39"	1' 41"
Percentage of total bitumen insoluble in 86° B. naphtha	8.04	13.94
Fixed carbon.....per cent.	4.93	7.10
Soluble in CS ₂ (total bitumen).....do.	99.91	99.89
Organic matter, insoluble.....do.	.07	.10
Inorganic matter, insoluble.....do.	.02	.01
Total.....do.	100.00	100.00

In the computation of cost data for the renewal surface treatment, shown in Table 18, the following unit prices were used:

Laborer, per 7½-hour day.....	\$1.75
Cart, per 7½-hour day.....	3.50
Sand, per cubic yard, on work.....	1.64
Bituminous material (per gallon):	
Section 1.....	.100
Section 2.....	.099
Section 3.....	.085
Section 4.....	.0775

TABLE 18.—*Materials and cost data for renewal surface treatments, Department of Agriculture Grounds, Washington, D. C., May 14-20, 1914.*

Section No.	Bituminous material.	Area (square yards).	Quantity of materials per square yard.		Cost per square yard (cents).							
			Bituminous material (gallons).	Sand (cubic yards).	Bituminous material.	Sand.	Cleaning surface.	Repairing surface.	Hauling and applying bituminous material.	Hauling and applying sand.	Miscellaneous.	Total.
1	Water-gas tar preparation.	1,363	0.177	0.0063	1.770	1.035	0.205	0.000	0.479	0.538	0.034	4.061
2	Asphaltic petroleum.....	1,095	.137	.0063	1.36	1.033	.234	.192	.330	.287	.085	3.521
3	Residual petroleum.....	706	.184	.0063	1.565	1.034	.165	.198	.644	.545	.066	4.217
4	Asphaltic petroleum.....	1,321	.145	.0065	.133	1.066	.106	.123	.459	.441	.053	3.381

¹ Clear.

² Clear, showed 0.0 per cent insoluble in dimethyl sulphate.

³ Soft, sticky, semisolid; a 315°-350° C. fraction showed 27.5 per cent, and a 350°-375° C. fraction showed 32.5 per cent insoluble in dimethyl sulphate.

SECTION NO. 1 (REFINED WATER-GAS TAR PREPARATION).

The first 100 feet of this section from the south end presented a markedly different appearance than the remainder, owing to the use on this portion of the section of bituminous materials of apparently different character for the 1914 treatment. The bituminous material used on this 100 feet was that remaining from the original treatment, and yielded a fine-grained, smooth appearance of a yellowish-gray color. The remainder of the section was treated with material obtained during the summer of 1914, and the treatment, which had at the time of inspection a reddish-brown color, had largely worn off in well-defined areas, showing the smooth mosaic surface of the original treatment. The section was smooth and had a true crown and uniform cross section.

SECTION NO. 2 (ASPHALTIC PETROLEUM).

This section, although it had a good crown, had developed several small pot-holes, which were rapidly becoming deeper, and along the south edge toward the east end of the section the drainage from the embankment adjoining the road had evidently been instrumental in causing deterioration of the surface mat. A surface treatment will be required the coming season.

SECTION NO. 3 (RESIDUAL PETROLEUM).

The surface treatment applied on this section during the summer of 1914, like the previous treatment, has shown a tendency to become muddy in wet weather and to shove gradually toward the side of the road. At the time of inspection the mat in the traveled way was largely worn off. Several small pot-holes were scattered over the road, and adjoining the Thirteenth Street intersection and toward Twelfth Street there were several large worn depressions which would require extensive patching. In general the road had a smooth regular crown and a smooth mealy surface.

SECTION NO. 4 (ASPHALTIC PETROLEUM).

This section had a smooth, hard surface free from waves and an especially good crown. Along the middle of the road there was evidence of slight and uniform wear over large areas, and the underlying macadam was beginning to show.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT CHEVY CHASE, MD.
1912.

BITUMINOUS CONCRETE, CEMENT CONCRETE, OIL-CEMENT CONCRETE, VITRIFIED BRICK, BITUMINOUS SURFACE TREATMENTS ON CONCRETE.

The original report of these experiments was published in Circular No. 99 of the Office of Public Roads and U. S. Department of Agriculture Bulletin No. 105. The following report covers the condition of the experiments when inspected on March 14, 1915.

EXPERIMENT No. 1 (BITUMINOUS CONCRETE—TOPEKA SPECIFICATION).

This experiment presents a hard firm surface, with some slight indication of waviness. The latter condition is most pronounced in the trap-rock section adjacent to the curb. The wear in this pavement is most evident where the surface is slightly below the top of the concrete curb, and in one place this has been broken and a slight depression has developed. The trap-rock section has a slightly darker color than that in which limestone was used, and the line between the two is easily discernible. Two lateral cracks were noted in the limestone section about 20 and 40 feet, respectively, south of its juncture with the trap-rock section. These cracks extend from the west curb about half way across the road. A small cup-hole was noted in the middle of the road about 60 feet north of Bradley Lane.

EXPERIMENT No. 2 (BITUMINOUS CONCRETE—DISTRICT OF COLUMBIA SPECIFICATION).

This experiment presents a smooth uniform surface on which the seal coat still remains practically intact. Two lateral cracks, both beginning at the east curb, were noted near the middle of the section in which trap rock was used. One of these extends about one-quarter of the distance across the road and the other about one-half the distance.

During the early summer of 1914 expansion in the concrete again caused a buckling of the surface at the joint between experiments Nos. 2 and 3. The stress developed was sufficient to force out the bricks which had been used in providing for this condition previously. The bricks were therefore removed, a clean trench was cut out entirely across the pavement for a width of about 1 foot and filled with Portland cement concrete.

EXPERIMENT No. 3 (CEMENT CONCRETE AND OIL-CEMENT CONCRETE—SURFACES TREATED WITH BITUMINOUS MATERIALS).

The several sections of this experiment have been permitted to wear without repairs, and the condition of the various sections at the time of this inspection was noted as follows:

(A) *Refined coal tar*.—The surface treatment has worn off in fairly large areas throughout the entire section.

(B) *Water-gas tar preparation No. 2*.—The surface has worn off in small areas throughout the entire section, in most cases not exceeding 1 square foot. This section is in an appreciably better condition than No. 1 through its retention of more of the original treatment.

(C) *Fluxed native asphalt No. 2*.—The bitumen in this section is still quite pliable, but the surface treatment has largely worn off over

the west half of the section, and there are a number of small worn areas in the east half.

(D) *Fluxed native asphalt No. 2 over water-gas tar preparation No. 1.*—The surface treatment is almost intact on the north half of this section, and the bitumen is still pliable. Over the south half, which includes the intersection with Thornapple Street, the surface treatment is in general worn off.

(E) *Fluxed native asphalt over native asphalt emulsion.*—The surface treatment is about two-thirds worn off this section, and the mat appears to be rather brittle.

(F) *Oil asphalt No. 1 over water-gas tar preparation No. 1.*—The surface treatment is almost entirely gone from this section.

(G) *Refined coal tar.*—The surface treatment is worn off to a great extent over the entire section.

(H) *Water-gas tar preparation No. 2.*—The surface treatment is still largely intact, although there are quite a number of small areas ranging in size from one-half square foot to 1 square foot where it is worn off. The majority of these are west of the center line of the roadway.

(I) *Fluxed native asphalt No. 2.*—On the east half of the roadway the surface treatment remains in fairly good condition, but the bitumen has become hard, and the surface treatment has disappeared from more than half of the area west of the center line of the roadway.

(J) *Oil asphalt No. 2.*—On the west third of this section, adjacent to the gutter, the surface treatment is about one-fourth gone, while over the remainder it is practically intact, excepting for one worn place about 1 square foot in area. Apparently the bitumen still possesses life.

EXPERIMENT NO. 4 (OIL-CEMENT CONCRETE) AND EXPERIMENT NO. 5 (CEMENT CONCRETE).

No particular difference was noted in the relative wear on the two classes of concrete. It is, however, interesting to note the difference in wear on the section constructed with trap rock on the grade adjacent to the vitrified brick experiment. The west half of the road, which carries the heavy traffic coming up the hill, is worn to an appreciably greater extent than the east half. The mortar appears to have abraded from around the particles of rock, thus yielding a much roughened surface. Over the remainder of the concrete experiment, extending south from the brow of the hill, the wear has been quite uniform over the entire surface. The table following shows the distance between cracks when measured on March 10, 1915.

TABLE 19.—Average and maximum distance between cracks in concrete experiments at Chevy Chase, Md., March 10, 1915.

Character of pavement.		Length.	Average distance between cracks.	Maximum distance between cracks.
Concrete.	Aggregate.			
Surface coated with bituminous material:		<i>Fect.</i>	<i>Fect.</i>	<i>Fect.</i>
Cement.....	Gravel.....	675	37	90
Do.....	Limestone.....	575	64	139
Oil-cement.....	Gravel.....	370	25	55
Do.....	Limestone.....	226	75	77
Surface exposed:				
Cement.....	Gravel.....	425	27	63
Do.....	Limestone.....	625	78	148
Do.....	Trap.....	300	23	50
Oil-cement.....	Gravel.....	260	26	47
Do.....	Limestone.....	200	50	84
Do.....	Trap.....	290	36	60

As noted in the previous progress report, the relative distances between cracks continue greater on sections constructed with a limestone aggregate than on those where trap rock or gravel were used.

EXPERIMENT No. 6 (VITRIFIED BRICK).

An inspection of this experiment showed no appreciable difference in wear between the several brands of brick. Three longitudinal cracks were noted, as follows:

In section D, a crack about one-third the length of the section and about 6 feet from the west curb. In section F, a crack about half the length of the section, beginning at the south end, and about 6 feet from the east curb. In section G, a crack about 6 feet long and about the same distance from the east curb as that in section F. These cracks are practically straight and so fine that they would hardly be distinguished in a casual observation. Their cause has not thus far been clearly ascertained.

A traffic census on this experimental road is taken every 13 days for a 24-hour period. A tabulation of the maximum and average of each class of traffic for the period between March 1, 1914, and March 1, 1915, is given in Table 20. The east side of the road carries outgoing traffic and the west side incoming traffic.

TABLE 20.—*Volume and character of traffic on Connecticut Avenue north and south of Bradley Lane.*

Vehicle.	North of Bradley Lane.				South of Bradley Lane.			
	Maximum.		Average.		Maximum.		Average.	
	East.	West.	East.	West.	East.	West.	East.	West.
Loaded 1-horse wagon	11	25	4	13	20	18	10	9
Unloaded 1-horse wagon	8	24	3	11	17	20	8	9
Loaded 2-horse wagon	15	103	6	35	32	96	12	28
Unloaded 2-horse wagon	40	75	10	19	83	52	25	10
Loaded 4-horse wagon	2	5	0	1	5	5	0	1
Unloaded 4-horse wagon	2	2	0	0	2	1	0	0
1-horse pleasure vehicle	7	18	3	8	21	18	8	8
2-horse pleasure vehicle	3	3	0	1	20	5	2	1
Rubber-tired horse vehicle	1	2	0	0	12	14	1	0
Saddle horse	8	12	2	3	15	11	3	4
Motorcycle	17	42	4	15	39	33	13	11
Excessively heavy vehicle	3	11	0	1	5	5	1	1
Motor runabout	23	173	7	54	169	139	60	44
Motor touring car	137	308	30	129	454	335	151	117
Loaded motor dray	12	47	4	20	31	34	19	14
Unloaded motor dray	14	20	2	8	17	19	5	8

SUPPLEMENTARY REPORT OF EXPERIMENTS AT CHEVY CHASE, MD., 1911 PROJECT.

BITUMINOUS CONSTRUCTION AND SURFACE TREATMENT.

The original reports of these experiments are given in Circulars Nos. 98 and 99, Office of Public Roads, and a supplementary report in U. S. Department of Agriculture Bulletin No. 105. The following report is based upon an inspection made January 28, 1915, after an extended period of cold wet weather.

SECTION NO. 1 (REFINED COAL TAR—PENETRATION METHOD).

In the summer of 1914 the surface presented a well-bound but rough appearance and gave evidence of considerable wear on the stone of the upper course. Therefore, on August 5 a cold surface treatment was applied, using a crude coal tar of the analysis given in the following table:

TABLE 21.—*Analysis of crude coal tar¹ used in cold surface treatment of section No. 1.*

Specific gravity 25°/25° C.....	1.146
Specific viscosity, 50 c. c., 50 ° C.....	5.0
Free carbon.....	per cent.. 8.62
Distillation:	
Water.....	By volume. By weight.
First light oils to 110° C.....	per cent.. 3.5 3.0
Second light oils (110°-170° C.).....	do... 3.3 2.5
Heavy oils (170°-270° C.).....	do... 3.5 .5
Heavy oils (270°-315° C.).....	do... 3 23.0 20.0
Pitch residue.....	do... 4 12.5 11.3
	do... 5 57.2 62.4
Total.....	do... 100.0 99.7

¹ Thin fluid.² Ammotifical.³ Clear.⁴ One-third solid.⁵ Hard, fairly dull, brittle.

The surface was swept by means of a rotary broom drawn by the automobile distributor, which applied the bituminous material. The application was immediately covered with $\frac{3}{8}$ -inch washed gravel, and the road opened to traffic. The bituminous material is charged at the rate of 6.6 cents per gallon, and sweeping and applying at 2.5 cents per gallon. The cost data for the treatment are given in Table 24. When inspected the surface was smooth and hard, with but few irregularities.

SECTION NO. 2 (REFINED COAL TAR—MODIFIED GLADWELL METHOD).

This section, although presenting a well-bound surface, is irregular and shows considerable wear, so that a surface treatment will be necessary during the coming season.

SECTION NO. 3 (FLUXED NATIVE ASPHALT—PENETRATION METHOD).

This section continues to present a smooth, well-crowned surface, but during the past year the seal coat has worn so that at the present time the surface has a mosaic appearance in some areas. There are a few other areas, especially in the north half of the section, where the seal coat is still intact, and no general treatment will be required during the coming season.

SECTION NO. 4 (GILSONITE OIL ASPHALT—PENETRATION METHOD).

This section, although well bound together, has an irregular surface, especially toward the gutter, so that it is rather rough under automobile traffic. In the depressions the stones are generally exposed, and probably considerable patching will be necessary in the spring.

SECTION NO. 5 (OIL ASPHALT—PENETRATION METHOD).

The appearance of this section has not changed appreciably since the last inspection, described in U. S. Department of Agriculture Bulletin No. 105. The surface is uneven, and in a few depressions the stone is somewhat loose. No raveling has occurred, however, and only minor repairs are now required.

SECTION NO. 6 (OIL ASPHALT—PENETRATION METHOD).

In general, this section has the same appearance as section No. 5. At the north end and on the west side of the trolley tracks the grade is 2 to 3 inches lower than that of the adjoining asphaltic concrete experiment, and it will be necessary in the spring to bring the surface to a corresponding grade.

SECTION NO. 7 (A AND B; OIL ASPHALT—PENETRATION METHOD).

The appearance of this section is not uniform. A has quite a mosaic effect, the northern portion of B has several small breaks which will need patching in the near future, and the southern portion has developed a few slight irregularities.

SECTION NO. 8 (REFINED WATER-GAS TAR PREPARATION—SURFACE TREATMENT).

The surface presents a very uneven appearance, owing apparently to the motion of the surface mat under traffic. A few small chuck holes have formed where raveling seems imminent, although in general the surface is very well bound. The section will probably require some repair and a surface treatment during the coming spring.

SECTION NO. 9 (ASPHALTIC PETROLEUM—SURFACE TREATMENT).

Toward the close of the season of 1914 this section began to give evidence of considerable wear. As in previous seasons, deterioration became more marked in the third of the road nearest the gutter and was most evident over the south half of the section, where an exceedingly heavy rain had interrupted the progress of the previous surface treatment. Two badly raveled places, each about half a square yard in area, and a few smaller depressions were patched by the penetration method with new 1½-inch limestone and a heavy oil-asphalt, rolled with a 10-ton roller, and finished by the application of a seal coat of the same bituminous material. Several humps were removed by cutting them flush with the surface by means of a mattock.

Immediately after these repairs had been made, on October 17 and 19, a surface treatment was applied over the entire section, using the same trade product as in the two previous treatments, and a fine torpedo sand. The surface was first thoroughly swept with fiber hand brooms, and the oil applied by allowing it to run from the bungs of the barrels and distributing it with push brooms. The oil was immediately covered with sand and the road opened to traffic. The bituminous material cost 8 cents per gallon, and the sand cost \$2.12 per cubic yard on the work.

Table 22 gives an analysis of the bituminous material, and the cost of surface treatment is given in Table 24.

TABLE 22.—*Analysis of asphaltic petroleum*¹ *used in surface treatment of section No. 9.*

Specific gravity, 25°/25° C.....	0.964
Flash point.....°C.	40
Burning point.....°C.	85
Specific viscosity, Engler, 25° C., 50 c. c.....	113.3
Loss, 5 hours at 163° C., 20 grams.....per cent..	26.46
Float test of residue ² at 32° C. (time).....	3' 46''
Float test of residue at 50° C. (time).....	1' 21''
Percentage of total bitumen insoluble in 86° B. naphtha.....	7.43
Fixed carbon.....per cent..	5.04
Soluble in CS ₂ (total bitumen).....do....	99.92
Organic matter insoluble.....do....	.06
Inorganic matter insoluble.....do....	.02
Total.....do....	100.00

¹ Fairly viscous, sticky fluid.² Very viscous, sticky fluid; glossy.

At the time of inspection the section generally presented a firm smooth surface. A few small cup-holes had formed where repairs were made before the last surface treatment, and were undoubtedly due to a poor distribution of oil asphalt in placing the patches.

SECTION NO. 10 (RESIDUAL PETROLEUM—SURFACE TREATMENT).

The development of irregular humps and ruts upon this section, noted in U. S. Department of Agriculture Bulletin No. 105, continued during the past year, until the surface was in such condition that it was deemed advisable to remove the surface mat as far as possible and re-treat the entire section. Accordingly the surface mat was broken up by means of a 3-ton scarifier, and as much of it removed as could be easily separated from the macadam stone. The old surface was then loosened by scarifying and picking, shaped with rakes, and brought to grade by the addition of a thin course of $\frac{3}{4}$ -inch limestone. After rolling, limestone screenings were scattered over the surface just sufficient in quantity to fill the surface voids. The surface was then thoroughly bonded by sprinkling with water and rolling.

The following table gives the materials and cost data per square yard for the reconstruction of the water-bound macadam surface.

TABLE 23.—*Materials and cost data for reconstruction of section No. 10, Chevy Chase, Md.*

Materials used per square yard:

1 $\frac{1}{2}$ -inch limestone.....	cubic yard..	0.001
$\frac{3}{4}$ -inch limestone.....	do.....	.016
Limestone screenings.....	do.....	.007

Cost per square yard:

1 $\frac{1}{2}$ -inch limestone.....	cents..	.173
$\frac{3}{4}$ -inch limestone.....	do.....	4.060
Limestone screenings.....	do.....	1.823
Sweeping old surface.....	do.....	.145
Removing old surface mat.....	do.....	2.970
Scarifying, and raking scarified surface.....	do.....	2.674
Spreading stone.....	do.....	1.041
Sprinkling.....	do.....	.764
Rolling.....	do.....	2.979

Total.....	do.....	16.629
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On November 3 and 4, after several days' traffic over the water-bound surface, the section was given a cold surface treatment with an asphaltic petroleum of the analysis given in Table 22. This was covered with washed $\frac{3}{8}$ -inch gravel. The bituminous material was applied by allowing it to run from the bungs of the barrels directly upon the road, which had previously been swept with hand brooms to remove loose material. The oil was broomed over the surface until no uncoated spots remained, and it was found that considerable brooming was necessary, owing to the fairly large amount of dust

still remaining. The oil was almost immediately covered with gravel, and finally the entire section was rolled lightly with an 8-ton tandem roller. After several days' traffic a subsequent light application of sand was found necessary to absorb the bituminous material that came to the surface. The material and cost data for the surface treatment is given in Table 24.

At the time of inspection the section had passed through a long spell of unfavorable weather, and its appearance demonstrated that the treatment was applied too late in the season. Numerous small but deep cup-holes had formed, extending into the water-bound macadam, and in general the entire surface had become very muddy. Considerable patching will be necessary at an early date.

SECTION NO. 11 (NATIVE ASPHALT EMULSION—MACADAM RESURFACING).

The section has had no treatment since it was resurfaced, and during the past year it has worn very uniformly, so that at the time of inspection the large stones were generally exposed over the entire surface. There are a few long waves and in a few places the large stones have apparently broken under traffic, but otherwise the surface is in excellent condition.

MAINTENANCE DURING THE YEAR 1914.

In addition to the general re-treatment above described, the patrol system of maintenance was continued during the year. Table 25 presents the total cost of this maintenance and the re-treatments, together with the total cost of each experiment to December 31, 1914.

A traffic census is taken every 13 days for a 24-hour period. A tabulation of the maximum and average of each class of traffic for the period between March 1, 1914, and March 1, 1915, is given in Table 20. The east side of the road carries outgoing traffic and the west side incoming traffic.

TABLE 24.—*Materials and cost data for surface treatment in 1914 of sections 1, 9, and 10 at Chevy Chase, Md., 1911 project.*

Section No.	Bituminous material.	Area of section (square yards).	Quantity of material per square yard.			Cost per square yard (cents).						
			Bituminous material (gallons).	Gravel (cubic yard).	Sand (cubic yard).	Bituminous material.	Gravel (cubic yard).	Sand (cubic yard).	Cleaning surface.	Applying bituminous material.	Applying sand or gravel.	Total.
1	Coal tar, crude.	1,581	0.316	0.007	.....	2.088	1.538	.....	10.791	0.625	.....	5.042
9	Asphaltic petroleum	761	.209	.....	0.0085	1.672	.....	1.811	0.356	.436	.434	4.709
10	do.....	1,013	.476	.011	.0020	3.807	2.328	.419	.339	.548	.571	8.111

¹ Includes cost of sweeping.

TABLE 25.—*Surface maintenance of 1911 experiments at Chevy Chase, Md., to December 31, 1914.*

Experiment No.	Date completed.	Area (square yards).	Maintenance cost of experiment.				Cost per square yard (cents).		
			1912	1913	1914	Total.	Construction.	Maintenance.	Total.
1.....	1911. Oct. 31	1,581	\$0.00	\$0.00	\$91.33	\$91.33	46.18	5.777	51.96
2.....	do.	705	.00	.00	.00	.00	77.62	.000	77.62
3.....	Nov. 18	1,555	.00	.00	.00	.00	64.69	.000	64.69
4.....	Nov. 8	1,555	.00	4.05	1.90	5.95	57.16	.383	57.54
5.....	Dec. 2	1,447	260.26	2.31	.67	263.24	58.27	18.192	76.46
6.....	Nov. 23	1,555	.00	3.47	.00	3.47	68.22	.223	68.44
7A.....	Dec. 5	131	1.43	.00	.00	1.43	59.96	1.092	61.05
7B.....	do.	848	67.88	.00	1.33	69.21	54.80	8.162	62.96
8.....	1912. Aug. 24	1,477		80.64	.00	80.64	39.59	5.460	45.05
9.....	June 4	761		39.65	44.78	84.43	42.01	11.095	53.11
10.....	Nov. 22	1,013		19.05	284.04	303.09	44.31	29.920	74.23
11.....	Dec. 16	377		.00	.00	.00	81.51	.000	81.51

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT JAMAICA, N. Y., 1911.

OIL-CEMENT CONCRETE, OIL-ASPHALT, TAR, AND FLUXED NATIVE ASPHALT.

The original report of these experiments was published in Circular No. 98, and reports of annual inspection and repairs may be found in Circular No. 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The following report covers the condition of the sections when inspected January 18, 1915.

EXPERIMENT NO. 1 (OIL-CEMENT CONCRETE).

In May, 1914, the Borough of Queens highway department patched the bare spots which were reported in the inspection of December, 1913, with an application of hot, refined coal tar and sand, and the addition of $\frac{3}{4}$ -inch stone in the deeper holes. The bare spots had developed somewhat larger in the section treated with water-gas tar products than in that treated with refined coal tar. At the time of the inspection the entire section was in very good condition with the exception of about 20 small bare spots where the carpet coat had worn off. The entire coat seemed to be worn very thin.

EXPERIMENT NO. 2 (CUT-BACK OIL ASPHALT—MIXING METHOD).

In May, 1914, the condition of this experiment was a little worse than in December, 1913, and in consequence the entire section was scarified to a depth of 3 inches and about one-third of the soft bituminous top mixture was thrown away. The remaining mixture was then shaped and lightly rolled to a thickness of about 2 inches, after which it was covered with a thin layer of $\frac{3}{4}$ -inch stone, thoroughly rolled, and opened to traffic. The following day a thin layer of trap-rock screenings was rolled in.

At the time of the inspection the experiment was again in very bad condition, and it appeared to be breaking up throughout its entire length. Numerous potholes, extending through the full thickness of the road, were forming, and the bituminous material appeared to have lost its life. The easterly 50 feet, however, continued in somewhat better condition than the remainder of the experiment.

EXPERIMENT NO. 3 (FLUXED NATIVE ASPHALT—MIXING METHOD).

Except where openings have been made for house connections, at about stations 5+40, 5+80, and 6+80, this section remains in very good condition. The patches placed at the openings are now somewhat below the original grade. Along the north side for the last 30 feet and for a width of from 3 to 4 feet there are a few waves about 3 feet long and 1 inch or less in depth. It is also possible in wet weather to notice slight waves, perhaps not over one-sixteenth inch in depth, extending entirely across the roadway. These were evidently caused by the manner of pouring the seal coat at the time of construction.

EXPERIMENT NO. 4 (REFINED COAL TAR—MIXING METHOD).

This section is in excellent condition except for the following imperfections: The edges on both sides are a little wavy, the waviness being more pronounced between stations 8+00 and 8+45 for a width of 5 feet on the north edge and between stations 8+45 and 9+00 on the south edge for a width of about 10 feet. At station 9+54 a pothole is forming on the north edge. The seal coat is gone from stations 10+68 to 10+98 for a width of about 5 feet on the south edge. At station 10+90, on the north side, a house connection was made and as the work of restoration was not properly done, the pavement at this point is not in first-class condition.

EXPERIMENT NO. 5 (CUT-BACK OIL ASPHALT—MIXING METHOD).

A rut developed in this section during the winter of 1913-14, and this, together with the holes reported in the last inspection report, was repaired in May, 1914. The deeper holes were patched with 1½-inch stone and hot refined coal tar, applied by the penetration method at the rate of 1½ gallons to the square yard. The rut was patched with ¾-inch stone, sand, and hot refined coal tar.

At the time of inspection the surface of the following portions of the experiment was found to be good: An irregular strip through the center from 6 to 8 feet in width, the whole intersection opposite Hardenbrook Street for a width of about 35 feet, the south side from stations 13+00 to 13+23, and the north side from stations 12+50 to 13+94. Over the remainder of the experiment the seal coat is disappearing, and potholes are forming. The whole section is wavy

on the edges, particularly the north edge, and there are indications that the bituminous material is losing its life. A pothole is forming just south of the center and on the west side of a patch at station 13+23.

EXPERIMENT No. 6 (OIL ASPHALT—PENETRATION METHOD).

This section continues in good condition, except for the fact that the seal coat seems to be wearing, while it is nearly gone on a strip about 2 feet wide 8 or 9 feet in from the south side from station 13+94 to station 14+38. The bituminous material of the seal coat over this area seems to lack life, and indications are that the strip will extend to the eastward. There is a narrow strip south of the center where the seal coat has been picked up by the wheels of some heavily loaded vehicle.

EXPERIMENT No. 7 (REFINED COAL-TAR—PENETRATION METHOD).

The general condition of this section is good. The surface is very satisfactory in the center, but along the sides the seal coat appears thin and is gradually disappearing. There is a bad depression on the north side at the junction of experiments Nos. 6 and 7, and three potholes were observed to be developing along the south side at stations 16+03, 16+15, and 16+94, respectively. The patch previously made over the conduit across the roadway is in excellent condition, but where one was made at station 16+90 near the south edge of the roadway the surface is below grade. Other than as above noted, the condition of this experiment remains about the same as when inspected, in December, 1913.

EXPERIMENT No. 8 (FLUXED NATIVE ASPHALT—PENETRATION METHOD).

This section is in about the same condition as reported in U. S. Department of Agriculture Bulletin No. 105, with the exception that a slight waviness has developed over the entire roadway. This is more noticeable at the sides, where the excess of bituminous material used in the original construction has pushed out.

EXPERIMENT No. 9 (OIL ASPHALT—PENETRATION METHOD).

The surface of this experiment is in good condition, with the exception of a few spots where the seal coat has been picked up or worn off, and these have partially healed over. Some would not be noticeable except on a rainy day. From station 19+20 to station 19+34 the seal coat has been worn off in the center of the road. From station 19+34 to the east end of the experiment there is a narrow strip where the seal coat was partially stripped off by the wheel of some heavily loaded vehicle.

There are some waves on the edges and a small hump on the south side at about station 18+54. The work done to fill in between this section and the wood-block pavement east of the experiment is in

very poor condition; the seal coat is gone, and quite a number of potholes have been formed, especially on the south side.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT NEW YORK, N. Y., AND RIDGEWOOD, N. J., 1910.

OIL-CEMENT CONCRETE.

The original report of these experiments was published in Circular No. 94, and the reports of annual inspections appeared in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The following report covers an inspection made in October, 1914.

EXPERIMENTS AT NEW YORK, N. Y.

This roadway was torn out in its entirety the week of September 27, 1914. The general condition of the surface of the road had gradually deteriorated from the condition shown by the inspection reported in December, 1913, and it was decided by the road maintenance department of the Borough of Richmond that the entire roadway should be torn up and a new one laid. It has therefore been replaced by bituminous concrete on a cement-concrete foundation.

EXPERIMENTS AT RIDGEWOOD, N. J.

Experiment No. 1.—The oil-cement concrete floor of the bridge over Saddle River was covered with a bituminous surfacing, as reported in the inspection made in December, 1913. The bituminous-macadam surfacing is in first-class condition, and the oil-cement concrete is not exposed.

Experiment No. 2.—The oil-cement concrete floor of the bridge over the Hohokus River is apparently in similar condition to that reported in December, 1913, excepting for the fact that it is a little more worn. The surface is even and smooth and has a rather flat cross section. The wear on this bridge floor still continues in the center of the roadway, since the sides for a width of from 3 to 4 feet from each edge are protected by dirt and leaves. In the center the large stones of the aggregate show on the surface, and at the ends of the bridge the edges of the concrete are rounded off to meet the surface of the adjoining macadam road.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT BOISE, IDAHO, 1910.

OIL-GRAVEL MACADAM.

The original report of this experiment was published in Circular No. 94, and reports of annual inspections were given in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The following report covers an inspection made on January 2, 1915:

The section which was constructed directly under the supervision of the Office of Public Roads carries voluminous and heavy suburban traffic, both vehicle and motor, and has received no maintenance or repairs since its original construction. A new 40-foot steel truss bridge was constructed across the slough last October, which resulted in unusually heavy additional traffic. For 20 feet on either side of the new bridge the macadam has been destroyed. The remainder of the experiment now presents an unsatisfactory appearance and is very wavy and much worn. There is a series of potholes of various sizes and depths, but there is, however, no apparent disintegration. The former shoulders have been used as a roadway until they have worn through the subgrade and are largely used by lighter traffic to avoid jolting. The crown is well maintained, and the penetration has been effective in general, with an excess of oil in places. The unevenness of wear, as previously noted, has been due primarily to a weak and poorly prepared foundation. Wherever the bond is broken the contributory cause appears to be large water-worn gravel too near the surface, and lack of uniformity in the distribution of the bituminous material, which latter permits early raveling.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT AMES, IOWA, 1910.

OIL-ASPHALT GRAVEL.

The original report of this experiment was published in Circular No. 94, and reports of annual inspections were given in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105.

When visited on December 19, 1914, there was about 1 inch of snow on this road. Scraping this snow from spots revealed about one-half inch of oily dust, covering a well-bonded surface. On warming bits of bituminous material in the hands it still developed a perceptible stickiness.

It was learned that an attempt was made in August to remove certain irregularities on the surface and to raise the center of the crown by means of a light two-wheeled single-blade grader. This cut away the high smooth places on the surface, leaving the gravelly mixture exposed. However, the traffic compacted this surface and it bonded again in very good shape. There was and is now some roughness perceptible to automobile travel caused by the uneven distribution of the material which was brought to the center for the purpose of raising the crown.

Traffic on this road is considerable, although it consists mainly of automobiles, carriages, and light wagons, since most of the heavy trucking enters the college grounds by another road.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT KNOXVILLE,
TENN., 1910.

TAR AND OIL PREPARATIONS.

The original report of these experiments was published in Circular No. 94, and reports of annual inspections are given in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The sections were again inspected November 18, 1914, and the following report was made:

The weather had been dry for some time, and the temperature was slightly above freezing. No repairs have been made or maintenance work done during the past year.

SECTION 1 (REFINED COAL TAR—PENETRATION METHOD).

This section is worn out, and the only places showing that tar was applied are those areas which were repaired a short time after the road was constructed. These patches stand out as islands about 2 inches above the surface of the road. Along each edge of the original pavement is a border of the tar mat from 12 to 18 inches in width and of varying thickness, caused by bleeding of the tar. Between these borders the surface has worn down to the foundation course of stone except at the islands referred to. This course of stone is wearing unevenly, and save for a few places where the tar penetrated it is water-bound macadam. It serves no further useful purpose as an experiment and should be rebuilt.

SECTION NO. 2 (REFINED TAR PREPARATION—PENETRATION METHOD).

Between the south end of this section and a street intersection 340 feet north, the surface is a succession of depressions and holes. About 300 feet from the south end of the section the tar-treated wearing course is continuous across the pavement for a short length, affording the first opportunity of studying the cross section of the pavement as affected by wear only. From the street intersection northward for some distance the surface is in fairly good condition; and although it is pitted with depressions of various sizes, there are few holes. In the last 100 feet there are quite a few holes, especially on the west side. This section should be reconstructed.

SECTION NO. 3 (OIL-ASPHALT—PENETRATION METHOD).

Except for a few depressions on the west side, the surface presents an excellent appearance. It has worn down to the wearing stone in places, resembling a bitumen-bound mosaic, but in no place has it lost its character as a bituminous surface, nor is there any evidence of raveling. Throughout the traveled portion the cross section is uniformly well preserved. Such bitumen as was dug out with a knife

blade was tough and pliable. The section will not require repairs to keep it in serviceable condition, but should the other sections be reconstructed the depressions in this section ought to be brought to grade.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT YOUNGSTOWN, OHIO, 1909.

SLAG, SLAG AND LIME, SLAG AND WASTE SULPHITE LIQUOR PREPARATION, AND SLAG AND TAR.

The original report of these experiments was published in Circular No. 92, and reports of annual inspections were given in Circulars Nos. 94, 98, and 99, Office of Public Roads, and U. S. Department of Agriculture Bulletin No. 105. The following report covers an inspection made October 26, 1914, after a period of about 10 days' rain:

SECTION NO. 1 (BLAST-FURNACE SLAG).

A length of approximately 65 feet of this section, beginning at the south curb of Mahoning Avenue, has been surfaced with a bituminous paving material and serves as an intersection apron to that avenue. Beyond the end of this pavement the section has not been disturbed, and it is in generally good condition. The ruts have become well defined, but they are shallow and wide, except for three depressions about 30 inches long in the west rut. In these depressions the binder has disappeared from the surface interstices of the stone of the wearing course, but the stones do not appear to have been loosened. The surface is otherwise smooth, uniformly worn, and free from large protruding stones.

SECTION NO. 2 (BLAST-FURNACE SLAG AND LIME).

Wide shallow ruts extend the entire length of the section, and a few large stones about 3 inches in diameter protrude about one-half inch above the general surface. Aside from these, the section has a clean-cut appearance and does not appear badly worn.

SECTION NO. 3 (BLAST-FURNACE SLAG AND WASTE SULPHITE LIQUOR PREPARATION).

The ruts referred to in the two preceding sections continue unbroken to the top of the slight grade near the middle of section No. 3, and there is no noteworthy difference in appearance between this and the preceding section. About the same number of large pieces of slag protrude from a unit of area, and there is no visible difference in wear. From the middle of the section down the grade to the beginning of section No. 4, neither the ruts nor the protruding stone are as pronounced as in the north half of the section.

SECTION NO. 4 (BLAST-FURNACE SLAG AND REFINED COKE-OVEN TAR).

The middle third of this section has settled very unevenly. Sand and slag chips have lodged in the depressions, from several of which the tar has entirely disappeared; in others, the pavement itself is disintegrating. The tar is hard and "dead," and the stone and tar can be separated under heel pressure. The ridges between the depressions are cracking.

While not as uneven as the middle third, the two end thirds are beginning to fail. The surface is so full of irregularities that riding over it is uncomfortable. In no place does the surface seem to have failed, but the tar is dry and lusterless and can be readily separated from the stone.

SECTION NO. 5 (BLAST-FURNACE SLAG).

Section No. 5 is still about $1\frac{1}{2}$ inches below section No. 4 at their junction. The northern two-thirds of this section is on a grade in a cut which shows evidence of seepage water. The surface of the road is rutted wider and deeper over this part of the section than over any other part of the experiments. However, there is no indication of failure of the pavement through raveling in the ruts. The south one-third of the section has a very satisfactory appearance; the ruts are not more than one-fourth inch deep, and the surface has a smooth, evenly worn, and uniform appearance.

SECTION NO. 6 (BLAST-FURNACE SLAG).

This section is wearing down into wide deep ruts. While in general the east rut is more pronounced than the west, there are several elongated depressions in the latter which have been swept clean of their binder and look as though they would ravel when dry. There are also three small spots in the section that seem to be the result of settlement rather than wear. The entire surface is mottled with large stone about 3 inches in diameter, protruding above the general surface.

SECTION NO. 7 (BLAST-FURNACE SLAG AND OPEN-HEARTH SLAG).

Some time during the summer, section No. 7 was swept clean of its screenings and dust, apparently in preparation for a surface treatment. In spite of this, there is no evidence of raveling. The whole section shows wide shallow ruts, with the large pieces of slag protruding. On the fill, from 100 to 200 feet from the south end of the section, the west rut is between 2 and 3 inches deep, and the depression over the culvert at the north end of the fill is a menace to traffic.

About 50 feet of the south end of the section was given a surface treatment of asphaltic oil during the summer when Price Road was treated. The treatment has worn uniformly.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT NEWTON,
MASS., 1908.ASPHALTIC PREPARATIONS, TAR PREPARATIONS, RESIDUAL OIL, AND MOLASSES-
OIL-LIME.

The original report of these experiments was published in Circular No. 90, and reports of annual inspections were given in Circulars Nos. 92, 94, 98, and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. No repairs have been made during the past year, and the following report covers an inspection made on October 5, 1914.

EXPERIMENTS NOS. 1, 2, 3, 4, 5, 6, AND 7 (ASPHALTIC PREPARATION—MIXING METHOD).

The first four of these sections, which have been reported as badly worn and in need of resurfacing, have continued to deteriorate so that almost none of the original surfacing shows. All of these sections are badly rutted and full of holes, with the exception of one piece of road, about 30 feet in length, at or near the beginning of experiment No. 3. This is in practically perfect condition for the entire width of the roadway.

Experiment No. 5 in its entirety is now in about the same condition as the first four experiments and is in need of resurfacing.

Experiment No. 6 continues to be in very good condition.

Experiment No. 7 contains about 20 places varying from depressions to holes, with about 14 holes which vary from 6 inches in diameter to an area of 4 square feet. It is evidently deteriorating rapidly through the "cupping" action. The three holes reported in Circular No. 99 as needing patching now show only traces of the binder, but there is a good mechanical bond in the foundation stone.

EXPERIMENT NO. 8 (RESIDUAL PETROLEUM—MIXING METHOD).

The eight small holes which were reported in U. S. Department of Agriculture Bulletin No. 105 have developed so that they vary from 6 inches in diameter to an area of 2 square feet. On this section there are indications of rutting and raveling near each quarter-point. The section should be patched and surface-treated if further deterioration is to be prevented, otherwise it seems probable that an inspection next year will show that it will need resurfacing. At the westerly side of Langdon Street there is evidence of a trench having been dug across the entire roadway in order to supply a fire hydrant, and the old material has been thrown back without any attempt at surface patching.

EXPERIMENTS NOS. 9 AND 10 (REFINED WATER-GAS TAR—MIXING METHOD).

These experiments appeared to be in practically as perfect condition as reported in U. S. Department of Agriculture Bulletin No. 105.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT GARDEN CITY,
DODGE CITY, BUCKLIN, AND FORD, KANS., 1908.

SAND-CLAY.

The original report of these experiments was published in Circular No. 90, and reports of annual inspections are given in Circulars Nos. 92, 94, 98, and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The following are reports of inspections made in 1914:

EXPERIMENT AT GARDEN CITY.

This road was inspected November 10, 1914, and wheat hauling with 4-horse teams was in progress at that time. There had been practically no rain since June, but the road had not deteriorated seriously.

There are no unrepaired holes. On the day of inspection 12 small holes and depressions were filled with fresh clay. There are five depressions varying from 2 feet square to 5 feet square which should be filled with clay before they are cut through.

The entire section has gradually flattened and should be reshaped. There are long wide ruts from one-half to three-fourths inch deep and the entire surface is finely pitted. It is not so rough, however, as to make riding uncomfortable.

The road is being maintained by dragging and by filling worn places in the manner indicated.

EXPERIMENTS AT DODGE CITY.

This road was inspected November 10, 1914. There had been no rain in this vicinity for some time and the soil was very dry. Wheat was being hauled to market, and the road was in such poor condition that the traffic from a large territory used a roadway 1 mile east of this.

About two-fifths of the sand-clay surface was broken through, and the sand from below had come to the surface. The failure had taken place over irregular areas. In some places it was confined to the rut or to the middle half of the road. There were occasional stretches 30 or 40 feet long that were in excellent condition. Consequently, the surface was so irregular and so deeply cut that traffic was confined to the ditches entirely.

The failure was no doubt largely due to the fact that the road had not been properly dragged after the heavy spring rains, and the weak places developed at that time were worn through by the heavy traffic during the long drought of the ensuing summer and autumn.

The road is now beyond repair, and reconstruction is necessary.

EXPERIMENT AT BUCKLIN.

This road was inspected November 11, 1914, when wheat hauling had begun.

The cross section of the road had gradually flattened, and two wide ruts (12 inches wide by 1 inch deep) had formed throughout its entire length. There were numerous places where the surface had begun to fail in the ruts, but only a few where the sand-clay surface had entirely cut through. The largest of the latter were in the immediate approach to the bridge. There were about 25 depressions and 5 holes through the surface.

Outside the ruts a slight ridge had formed, the outer edges of which were overgrown with grass. The ditches were covered with a heavy growth of grass, but were well defined and open.

The depressions and holes should be filled with clay, and the road should be reshaped with a grader to prevent the formation of secondary ditches inside the existing ones.

EXPERIMENT AT FORD.

This road was inspected November 11, 1914. It was generally in good condition except within 100 feet of the bridge, where there were three holes cut through the sand-clay surface. In the remainder of the road there were several depressions which should be filled with fresh clay before dragging the road. There were two ruts extending the entire length of the road, which were about 12 inches wide and 1 inch deep. The ditches were well defined, and the roadway would be in excellent condition if it were dragged and repairs made at the places noted.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT BOWLING GREEN, KY., 1907.**KENTUCKY ROCK ASPHALT.**

The original report of this experiment was published in Circular No. 89, and reports of annual inspections are given in Circulars Nos. 90, 92, 94, 98, and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The inspection on which the following report is based was made on November 5, 1914.

The experiment has had no maintenance whatever, and owing to the accumulation of dirt on the surface it was impossible to make a thorough inspection. Such information as could be gained by cleaning the surface in places and digging into depressions seemed to indicate that the condition was not greatly changed since the last inspection. There are numerous holes throughout the west end, but the relative number decreases as the east end is approached. In many of these holes the rock asphalt has practically disappeared, and the remaining stones are loose. In areas where the rock asphalt has not failed the surface remains quite smooth.



BULLETIN No. 258

Contribution from the Office of Experiment Stations
A. C. TRUE, Director



Washington, D. C.



July 13, 1915.

LESSONS IN ELEMENTARY AGRICULTURE FOR ALABAMA SCHOOLS.

OUTLINED BY MONTHS.

By E. A. MILLER, *Specialist in Agricultural Education.*

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INTRODUCTION.

The fact that many States now require the teaching of agriculture in the elementary grades makes it important that much attention be given to the subject matter. This bulletin presents lessons in agriculture adapted to the conditions in Alabama. The purpose is to suggest a plan by which the States may adapt instruction in agriculture to local needs. The selecting of a particular State in this instance has been made to show the manner in which such a plan may be definitely worked out. Although the department does not contemplate issuing publications of this kind for other States, it stands ready to co-operate in making studies as to agricultural and school conditions and in outlining courses adapted to the conditions.

A monthly sequence plan is followed in the presentation of these lesson topics, the purpose being to teach principles at the season when they are or should be practiced. Only the salient features of each lesson topic are outlined in this publication, but specific references are made to the State adopted textbook in agriculture and to

¹ Prepared under the direction of C. H. Lane, Chief Specialist in Agricultural Education, Office of Experiment Stations, United States Department of Agriculture, in cooperation with the Alabama Polytechnic Institute, C. C. Thach, president, Auburn, Ala.

NOTE.—This bulletin is prepared especially for the use of rural school teachers in Alabama.

bulletins of the Alabama Polytechnic Institute, Auburn, Ala., and to Farmers' Bulletins of the United States Department of Agriculture, Washington, D. C. The references are made for two purposes, namely, to supplement the textbook material and to provide a reading course for the teacher. Any teacher who secures these bulletins and studies them carefully will have completed a good elementary course in agriculture. It is suggested that agriculture and some other subject such as physiology be alternated throughout the school year. Two lessons a week for eight months are necessary to complete the work in agriculture. If the school year is shorter, it will be necessary to have three lessons a week to complete the course.

Practical exercises are suggested in connection with each lesson. If this course is to be made most effective, however, the practical work should take the direction very largely of club activities or home projects.

The correlation exercises in connection with each lesson are intended to be suggestive. The teacher should vitalize the other public-school subjects by utilizing things most familiar to the pupils, such as farm, home, and school-life facts and incidents. It is understood that the correlation suggestions are not necessarily a part of the lesson in connection with which they appear, but are to give local coloring to the other subjects.

SEPTEMBER.

LESSON ONE.

SUBJECT: SOIL. TOPIC: WINTER COVER CROPS.

Importance.—During the summer and early fall the plant life in the soil makes available much valuable plant food. Unless this is conserved the weathering agencies leach it out and wash it away during the winter months.

Kinds of cover crops.—(1) Small grains, such as rye, barley, wheat, and oats; (2) legumes, such as crimson clover, bur clover, and vetch.

Seeding.—Such crops are seeded while other crops are occupying the ground, hence the necessity of hand sowing or using a one-horse drill.

Class assignment.—Duggar's,¹ pp. 86-92. Teachers supplement this lesson with notes from Farmers' Buls.² 326, 427, and 507; Alabama Experiment Station Buls. 147 and 165.

Practical exercises.—Study roots of leguminous plants and compare them with the roots of nonleguminous plants. Note the tubercles.

¹ Duggar's Agriculture for Southern Schools.

² Farmers' Bulletins may be had, as long as available, by writing to the United States Department of Agriculture, Washington, D. C.

Of what value are they? Club members should sow cover crops on plats.

Correlations.—Language and drawing: Make drawing and describe a leguminous plant, including roots with tubercles, stem, leaves, and seed pods. History: Read "Alfalfa," p. 229, Farm Life Reader, Book Five.

LESSON TWO.

SUBJECT: CROPS. TOPIC: SEED-CORN SELECTION.

Select in the field stalks that have surpassed their neighbors under average conditions as to distance and soil fertility; that are thrifty, of average height, strong, and tapering; that have strong brace roots and an abundance of leaves; that have at least two good ears at a medium height, possessing moderately long shanks, close-fitting husks, and well-covered tips.

Mark ears that are 8 to 10 inches long, with an average circumference three-fourths of the length of the ear; that have medium-sized cobs, straight rows of kernels extending to the tips and butts; and that have long, wedge-shaped, firmly set kernels true to type as to denting and color.

Storing seed.—Later, when seed is mature, gather and store out of reach of small animals. If necessary, fumigate for weevils or grain moths.

Class assignment.—Duggar's, pp. 129-135. Teachers should supplement the lesson with notes from Farmers' Buls. 313, 415, 537, and 617.

Practical exercises.—Teacher should accompany pupils to near-by field and give them practice in selecting proper stalks and marking ears. Club members should select seed for the next crop.

Correlations.—Language: Write an account of the field trip. Drawing: Ideal and improper ears, ideal and ill-shaped grains furnish drawing material. History: Study the development of the corn-club movement. Organize a school club. Get extension literature from the Alabama Polytechnic Institute, Auburn, Ala. Arithmetic: Collect community data on increased yields due to seed selection and develop problems adapted to the needs of the pupils.

LESSON THREE.

SUBJECT: POULTRY. TOPIC: TYPES AND BREEDS.

Class assignment.—Duggar's, pp. 310-313. Teacher should supplement the lesson with notes from Farmers' Buls. 51 and 528.

Practical work.—Make a poultry survey of the community, ascertaining and tabulating the different types and breeds. Secure the help of the members of the class and other pupils.

Correlations.—Language: Tabulating the facts with reference to the poultry of the community furnishes language material. Drawing: Make sketches of feathers from different parts of the body of an individual of each breed studied. Arithmetic: Develop problems on the value of the poultry of the community as indicated by the survey.

LESSON FOUR.

SUBJECT: SOILS. TOPIC: MOISTURE.

Kinds of moisture.—Free, capillary. Each defined. Movements of each kind.

Effects of moisture on breaking land, subsoil plowing, preparing seed bed.

Class assignment.—Duggar's, pp. 65-68 and 70-72.

Practical exercises.—Perform exercises suggested in Duggar's, pp. 66, 67, and 69.

Correlations.—Language: Write up results of practical exercises and copy in notebooks. Drawing: Make sketches of materials used in practical exercises.

LESSON FIVE.

SUBJECT: CROPS. TOPIC: SMALL GRAINS AND CLOVERS.

Small grains.—Wheat, oats, rye, barley. Preparation of soil, time of sowing, fertilizers, rate of seeding, varieties, treatment to prevent diseases.

Clovers.—Kinds, uses, time, manner and rate of seeding, need and methods of inoculation.

Class assignment.—Duggar's, pp. 136-143 and 174, 177, and 178. Teacher should supplement the lesson with notes from Farmers' Buls. 427, 436, 518, 550, 579, and 646.

Practical exercises.—(1) Collect in bottles, bring to school, and label the different kinds and varieties of grains and clovers studied in this lesson. See Farmers' Bul. 586. (2) Study these seeds to learn to identify them. (3) Take a given amount of seed of each kind, pick out the good, pure seeds and separate from the impure and the unsound. Would it be advisable to sow impure seed?

Correlations.—Language: Develop the notes taken in connection with the foregoing exercises and copy in the notebooks. Drawing: Make enlarged drawings of each kind of seed, giving proper color. Arithmetic: Develop problems on the purity of seed, based on results obtained in the practical exercises.

LESSON SIX.

SUBJECT: FARM ANIMALS. TOPIC: SOW AND PIG MANAGEMENT.

Since it is possible to have fall, winter, and early spring pastures in Alabama, a fall litter of pigs is desirable. September seems to be the most desirable month for the pigs to be born. The following points should be emphasized in this connection: (1) Providing the farrowing pen with fenders to prevent mashing or overlying pigs, (2) providing bedding for young pigs, (3) feeding the sow, (4) teaching the young pigs to eat, (5) feeding pigs before weaning, (6) time of weaning, and (7) selecting breeding stock.

Class assignment.—The teacher should be provided with Farmers' Buls. 205 and 566. Give pupils notes covering the foregoing points found on pages 28-34 in No. 205, and pages 9, 10, and 11 in No. 566. See also Farmers' Bul. 411.

Practical exercises.—Insist on pig-club members getting their pigs in condition for the county fair. Make a portable hog house like the one described on page 12 of Farmers' Bul. 566. This may be used for a permanent house. One of its advantages is that it can be moved from place to place.

Correlations.—Language: Describe a portable hog house. Drawings: Make simple drawings of the portable hog house and the open farrowing pen. Geography: Iowa, Illinois, Missouri, Indiana, Nebraska, Ohio, and Kansas are the seven leading hog-producing States. Locate them on the map. What is the relation between the crops grown and raising hogs? Is it necessary for Alabama to buy pork from these States? History: Organize a pig club. Study the pig-club development in the State. Arithmetic: Find the cost of constructing portable hog houses. Base calculations on size of house and local prices of materials.

LESSON SEVEN.

SUBJECT: INJURIOUS INSECTS. TOPICS: BOLL WEEVIL, POTATO BEETLE, COTTON BOLL-WORM.

Class assignment.—Duggar's, pp. 260-271. Teachers should supplement the lesson with notes from Farmers' Buls. 290, 500, and 512; Alabama Experiment Station Buls. 178, 164, and 146.

Practical exercises.—Collect specimens of insects studied, place them in bottles, and bring to school. Furnish them with materials on which to feed and study their development.

Correlations.—Language: Copy in notebooks results of observations with insects. Drawing: Make sketches of the insects in the different stages of their life history. Also make drawings of the parts of plants attacked showing the nature of the injury. History:

Study the origin, spread, and extent of damage of the boll weevil. Arithmetic: Secure data from the homes of the pupils and develop problems as to the damage done to crops by insects studied in this lesson.

LESSON EIGHT.

SUBJECT: FARM ANIMALS. TOPICS: (1) POULTRY MANAGEMENT; (2) DISEASES—DIARRHEA, SCALY LEGS.

Class assignment.—Duggar's, pp. 306–309. The teacher should supplement the lesson with notes from Farmers' Buls. 287 and 530.

Practical exercises.—Have pupils report to the class any diseases or insect pests of poultry in the community. Compare symptoms with those found under the different diseases in Farmers' Bul. 530. Study remedies and apply them. Have each member of the class make drinking fountain for poultry.

Correlations.—Language: Have each pupil describe the poultry watering device used at his home. Drawing: Sketch a drinking fountain. History: Organize a poultry club. Read Farmers' Bul. 562. Arithmetic: Have members of class report the loss of poultry at their homes during the year due to disease. Develop problems on the value of the poultry lost.

OCTOBER.

LESSON ONE.

SUBJECT: POULTRY. TOPIC: HOUSES.

The site should be convenient to the attendant, well drained, and protected from exposure.

The house should be so constructed as to be convenient, cheerful, dry, well ventilated, free from drafts, and economical.

The styles are colony, continuous, and double-decked.

The parts.—The floor may be cement, board, or earth; walls, single with outside coat of paper or double; the roof, shed, gable, combination, A-shaped, or sloping front. There should be 4 to 6 square feet for each bird. For ventilation have an open front facing the south.

Fixtures.—These consist of droppings board, roosts, nests, feed hoppers, water pans, and dust baths.

Class assignment.—Farmers' Buls. 287, pp. 7–11, and 528, p. 9; Duggar's, p. 309.

Practical exercises.—(1) Have pupils make drinking fountains. See Duggar's, p. 309. (2) Require pupils to report on the poultry houses at their homes. If possible have pupils visit a modern poultry house in the community.

Correlations.—Language: A written description of the poultry house at each pupil's home. Drawing: Sketch drinking fountains

and feed hoppers. Geography: State the geographical conditions to be considered in locating and building a poultry house. Arithmetic: Have pupils submit plans for poultry houses; develop problems on the cost of material.

LESSON TWO.

SUBJECT: CROPS. TOPIC: THE COTTON PLANT.

Subtopics.—Importance of the crop; kinds of cotton; short staple upland varieties; satisfactory varieties; and improving cotton.

Class assignment.—Duggar's, pp. 144–150; supplement with notes from Alabama Experiment Station Buls. 130 and 153.

Practical exercises.—Have members of the class bring to school the different varieties of cotton found in the community. Classify the varieties under the main groups, p. 147, Duggar's.

Correlations.—Language: Have pupils write letters to the United States Department of Agriculture, Washington, D. C., and the Alabama Experiment Station, Auburn, Ala., for the bulletins referred to in this publication. Select and mail the best letter in each case. Drawing: Require pupils to sketch stalks and bolls of varieties of cotton examined. Arithmetic: Pick and weigh 25 bolls of each variety studied. Develop problems as to the number of bolls per pound. How many stalks per acre of each variety examined would be necessary to produce 1,500 pounds of seed cotton?

LESSON THREE.

SUBJECT: HORTICULTURE. TOPIC: HOME ORCHARD.

Destroying sources of disease.—Remove from the orchard and burn all rubbish, mummies, decayed fruit, and dead trees.

Selecting site for new orchard.—Select a good loam soil, elevated, with north or northwestern exposure and protected from strong prevailing winds.

Preparation of soil.—Remove stumps, stones, and rubbish; break the soil thoroughly to a reasonable depth and harrow thoroughly.

Class assignment.—Supplement the foregoing outline with notes from Alabama Experiment Station Buls. 132 and 156, and Farmers' Buls. 154, 491, and 631.

Practical exercises.—Practice distinguishing diseases by the appearances of mummies of apples, peaches, pears, and quinces. See Alabama Experiment Station Bul. 132. Mummies should be brought to school for this purpose.

Correlations.—Language and drawing: Make written descriptions and drawings of mummified fruit. Geography: Have each pupil outline the home farm, showing the location of the orchard with reference to dwelling, barns, etc. History: List the leading varieties

of apples and peaches, and have each member of the class prepare an account covering the date of introduction, productivity, keeping and shipping qualities of some one variety. Arithmetic: Make out an order for a given number of trees and find the cost based on nursery prices.

LESSON FOUR.

SUBJECT: FARM ANIMALS. TOPICS: (1) MANAGEMENT OF MEAT HOGS; (2) PROVIDING WINTER PASTURES.

Management of meat hogs.—It is too expensive to fatten meat hogs on corn, hence a fall pasture of peanuts, cowpeas, or soy beans should be ready for use this month. Turn hogs on pasture and supplement with corn. When the pasture is exhausted finish off the hogs with corn.

Winter pastures.—Any one of the following crops furnishes pasturage within 60 to 120 days: Rye, wheat, rape, bur clover, oats, and vetch.

Class assignment.—Give the pupils notes on the foregoing topics from Farmers' Bul. 411 and Alabama Experiment Station Bul. 168.

Practical exercises.—Have each boy in the class assume charge of at least one pig that is to be fattened. The pig should be weighed to begin with. If abundant pasturage is furnished, feed the pig 2 per cent or one-fiftieth of its weight of concentrated food each day. If pasturage is not provided, feed 4 per cent or one twenty-fifth of the pig's weight of concentrated food. The pig should be weighed once each week. When the pasture is exhausted place the pig in a small lot and finish off with concentrated feed.

Correlations.—Language: Have pupils prepare tables to keep weekly records of the weights of the pigs and daily records of the weight of the feed. History: Require members of the class to make a survey of the community as to the breeds of hogs and write accounts covering the dates on which each breed was introduced and the success with which each has been grown. Arithmetic: Develop problems as to cost of feeding the pupils' pigs.

LESSON FIVE.

SUBJECT: DAIRYING. TOPIC: CARE OF YOUNG CALVES.

Feeding.—Calves should be taken from the mother when 2 days old and fed out of a bucket. Feed each calf $1\frac{1}{2}$ to 2 quarts of whole milk three times a day until 2 weeks old. At two weeks of age begin to substitute some skim milk for whole milk and decrease the whole milk so that the calf will be on a skim-milk ration when a month old. When the calf is 2 weeks old teach it to eat ground and

cracked food by rubbing bran on its nose just after feeding it milk. Calves learn early to eat hay and should be fed a liberal amount of good hay. They should have an abundance of water and salt and should have access to a pasture.

Shelter and attention.—Sheds should be provided at night and on rainy, stormy days. Should disorder of the alimentary canal develop as a result of feeding skim milk the following treatments are suggested: (1) Tablespoonful of castor oil. (2) Mix an ounce of formalin with a pint of water and give five teaspoonfuls in milk at night.

Practical exercises.—Raise funds and secure a Babcock tester. One may be bought for \$5. Learn to test milk for butter fat. Have pupils bring to school samples of milk for this purpose.

Correlations.—Language: Record in the notebook results of milk tests. Drawing: Require pupils to draw the devices used in testing milk. Geography: Jefferson, Mobile, Montgomery, and Blount are among the leading counties engaged in the dairy business. Locate these counties on the State map and suggest reasons for their engaging in this industry. Arithmetic: Develop problems as to the amount and value of butter fat produced by each cow tested.

LESSON SIX.

SUBJECT: CROPS. TOPIC: SWEET POTATOES.

Subtopics.—(1) Varieties, (2) when to harvest, (3) how to harvest, (4) handling, (5) storing, (6) selecting seed, and (7) marketing.

Class assignment.—Duggar's, pp. 163, 164. Supplement the lesson with notes from Farmers' Buls. 533 and 548.

Practical exercises.—(a) Have members of the class bring to school specimens of each variety of sweet potatoes grown at their homes. Learn to identify each variety. (b) Have each member make a written statement covering the following points as practiced at home: (1) Tools used in digging potatoes, (2) vessels used in carrying potatoes to storing place, (3) kind of potatoes selected for seed, and (4) method of storing.

Correlations.—Language: The foregoing report provides written work. Drawing: Different varieties of potatoes and tools used in digging furnish material for drawing exercises. Arithmetic: Have pupils report areas and yields and develop problems as to the yield per acre in each case, the average yield per acre in the community, and the value of the potato crop of community based on present prices. Estimate profit to the community if the potato crop should be well handled and stored and sold in midwinter and in early spring.

LESSON SEVEN.

SUBJECT: POULTRY. TOPIC: FEEDING LAYING HENS.

Subtopics.—(1) The importance of feeding, (2) kinds of feeds, (3) methods of feeding, and (4) grits and other substances.

Class assignments.—Duggar's, pp. 306–309. Supplement the lesson with notes from Farmers' Buls. 287, pp. 19–26, and 528, p. 10.

Practical exercises.—Practice testing eggs. See directions in Farmers' Buls. 287, p. 28, and 562, pp. 9, 10.

Correlations.—Language: Describe a good egg and a bad egg as they appear when tested. Drawing: Make drawings of good and bad eggs as they appear when tested. Geography: Answer the following questions: Are the eggs tested in the homes of the community before being marketed? Are eggs sold to a general merchant, poultry dealer, or shipped by parcel post direct to the consumer? Are eggs sold by the dozen or by the pound? Locate on the map the community's principal egg market. How are eggs prepared to ship by parcel post? (See Farmers' Bul. 594.) Arithmetic: Develop problems on the cost of feeding flocks of chickens at homes of the pupils or flocks belonging to club members. Estimate 4 pounds of dry feed daily to each 100 pounds of live weight of poultry.

LESSON EIGHT.

SUBJECT: CROPS. TOPICS: (1) SUGAR CANE; (2) PEANUTS.

Sugar cane.—The plant, varieties, soils, fertilizers, yields, uses.

Peanuts.—Importance, varieties, harvesting, uses, best type of soil for successful growing.

Class assignment.—Duggar's, pp. 154–161, 165, 166. Supplement lesson with notes from Farmers' Bul. 431.

Practical exercises.—(1) From what is sugar cane grown? Examine several stalks to note the number of nodes (joints), the length of the internodes at different parts of the stalk, the buds from which young plants grow. (2) Carefully remove a number of peanut plants from the soil. Examine the roots for tubercles. Are peanuts borne on roots or stems? Take the nuts from several vines and measure or weigh each lot separately.

Correlations.—Language and drawing: Require members of the class to write descriptions and make drawings of peanut plant, showing all the parts. Arithmetic: Count the peanut plants on a plat 20 feet square. Find the average yield per vine. From these figures develop problems as to the yield per acre and the value of an acre's yield at local prices.

NOVEMBER.

LESSON ONE.

SUBJECT: CROPS. TOPIC: THE BLACK WEEVIL OF CORN.

Subtopics.—Life history, damage done; preventive measures—seed selection, value of husk covering, resistant varieties, harvesting, storing; fumigation—room, dose, application of carbon disulphid, precautions.

Class assignment.—Alabama Experiment Station Bul. 176. The teacher should give pupils notes on the subtopics from this bulletin.

Practical exercises.—(1) One ounce carbon disulphid is required as a dose to fumigate 3 cubic feet of ear corn. Secure a small box, fill it with ears of corn affected with weevils, apply the proper dose over the surface of the corn, cover the box tightly, and keep it away from fire. After 7 to 10 days remove the cover, ventilate the box, examine the corn, and note results. (2) Secure 10 ears of sound corn, 10 partially damaged by weevils, and 10 seriously damaged. Shell each lot, carefully weigh equal measurements of each, and compare.

Correlations.—Language: Describe an ideal weevil resistant ear of corn. Drawing: Make drawings of ears and grains seriously affected by weevils. Arithmetic: From the facts ascertained in exercise 2 develop problems as to the damage done the crops from which the ears were selected.

LESSON TWO.

SUBJECT: HORTICULTURE. TOPIC: SETTING AN ORCHARD.

Distance between trees.—Apples: 16 by 32 feet, 20 by 20 feet, 24 by 24 feet. Good distance for the cultivation of other crops. Peaches: Trees may be set in squares or triangles, the rows parallel. Squares 18 by 18 feet seem preferable. Plums, cherries, and pears usually require same distance as peaches. Pears and cherries may require greater distance.

Seasonal varieties.—Apples: Yellow Transparent, Red Astrachan, Red June, Golden Sweet, Maiden Blush, Horse, Hackworth, Ben Davis, Winesap, Shockley, Mammoth Blacktwig, Yates, Reese Seedling. Peaches: Mayflower, Sneed, Greensboro, Carman, Hiley, Champion, Belle of Georgia, Elberta, Crawford Late. Plums: Red June, Abundance, Wild Goose, Burbank, Gold, Satsuma. Cherries: Early Richmond, English Marrello. Figs: Celeste or Celestial, Brown Turkey, Lemon. Pear: Leconte, Kiefer, Goshen, Russet or Apple.

Digging holes, pruning tops and roots.—These are important features of the lesson, and should be given proper emphasis.

Class assignment.—Duggar's, pp. 219–224. Teacher should supplement lesson with notes from Farmers' Buls. 113, 154, 482, 491, 631, 632, and 633.

Practical work.—Make a trip to a farm where fruit trees are being set. Take notes on the method. Set trees and shrubbery on school grounds this month. See Farmers' Buls. 185 and 218.

Correlations.—Language: Require of the pupils written reports as to the kinds and varieties of fruits at their homes. Drawing: Have each pupil submit a plan for a home orchard, showing the location of the different kinds of fruits. History: Study the horticultural law of the State. Secure a copy from the Alabama Polytechnic Institute, Auburn, Ala. Arithmetic: At the prevailing prices of plants develop problems to determine the cost of the orchards planned by the pupils.

LESSON THREE.

SUBJECT: FARM ANIMALS. TOPIC: HOG HOUSES, PENS, TROUGHS, AND FENCES.

Houses.—Permanent and portable. Features of construction: Location, light, ventilation, warmth, and cleanliness.

Pens.—The number, size, location.

Troughs.—Kinds, material, length, braces.

Fencing.—Permanent, portable, and hurdles. Purposes and material.

Class assignment.—Cover the foregoing outline with notes from Farmers' Buls. 205 and 438.

Practical work.—(1) Make a trip with the class to a modern hog house. Study and take notes on its construction. (2) Require each member of the class to submit a written report covering the conditions at home with reference to these points: The housing, troughs, pens, and pasture fencing for hogs. Discuss these reports in class.

Correlations.—Language: Written work is provided for in exercise 2. Drawing: Draw to scale ground plan of a hog house, also different kinds of hog troughs. Arithmetic: Develop problems on the cost of hog houses, fences, and troughs.

LESSON FOUR.

SUBJECT: SOILS. TOPIC: APPLICATION OF LIME.

Reasons for applying lime at this time.—(1) Land is being plowed, (2) young plant roots are not injured, and (3) acts upon turned stubble or vegetable matter.

How lime helps the soil.—(1) Supplies plant food, (2) makes other plant food available, (3) sweetens sour soils, and (4) makes compact soils porous and porous soils compact. Crops not benefited or indifferent to lime. How often should lime be applied, and in what quantities?

Class assignment.—Duggar's, pp. 112–115. Supplement the lesson with notes from Farmers' Bul. 77, Alabama Experiment Station Bul. 161.

Practical exercises.—See "Exercise" and "Note to teacher," Duggar's, p. 115.

Correlations.—Language: Describe the things that take place in the foregoing exercise. Arithmetic: At the prevailing price of lime, find the cost of applying a ton per acre to a 10-acre field. What is the weight of a barrel of lime? How many barrels would be necessary to apply on a 10-acre field?

LESSON FIVE.

SUBJECT: DAIRYING. TOPICS: PRODUCTION AND CARE OF MILK.

Class assignment.—Duggar's, pp. 323–325. Supplement with notes from Farmers' Buls. 349 and 541.

Practical exercises.—See "Note to teacher," Duggar's, p. 325.

Correlations.—Language: Have each pupil write and read in class an account covering such points as precautions observed for cleanliness in milking, vessels used to keep milk pure, and method of keeping it cool. Drawing: Sketch different kinds of milk pails. History and geography: Milk is a natural and complete food. Its use antedates history. List the dairy products used in the community. Which are bought? Wisconsin is the leading State in dairying. Locate this State on the map. Arithmetic: Make a survey of the community as to number of cows giving milk and the amount of milk produced. Develop problems to determine the average production per cow, the total production per year, and the value based on local prices.

LESSON SIX.

SUBJECT: POULTRY. TOPIC: MARKETING EGGS.

Subtopics.—Testing, sorting, packing, and shipping; methods of selling; parcel post—kinds of containers, securing containers, reaching the consumer.

Class assignment.—Give notes from Farmers' Buls. 287, pp. 40, 41, and 594, pp. 5–13.

Practical exercises.—Either have some member of the class to bring to school a basket of eggs or go with the class to the pupil's home and practice testing and sorting. See Farmers' Bul. 562.

Correlations.—Language: Make a community poultry survey covering such points as the number of hens, the weekly egg production, and the method of selling eggs. Have the pupils prepare blanks for this purpose and compile the facts.

Arithmetic.—Develop problems based on the foregoing facts.

NOTE.—Supplement this lesson with a study of bad habits of poultry. See Farmers' Bul. 287, p. 47.

LESSON SEVEN.

SUBJECT: FARM ANIMALS. TOPIC: WINTER FEEDING OF BABY BEEVES, MATURE BEEVES, AND HORSES.

Baby bees.—Fattening and marketing calves from 8 months to a year old may be made profitable. The high price paid for beef animals in the winter and early spring makes it advisable to begin now to get animals ready for market. Pastures and open fields should be utilized as long as profitable. These should be supplemented with a part ration at the outset. The ration should be gradually increased as the pastures give way and as the fattening period advances. The fattening period should usually extend approximately 100 days.

Rations.—(1) Cottonseed meal, 2 parts; corn-and-cob meal, 1 part; equal parts of cottonseed hulls and legume hay. (2) Cottonseed meal and equal parts cottonseed hulls and legume hay. (3) Cottonseed meal, 1 part; corn-and-cob meal, 2 parts; and equal parts of cottonseed hulls and legume hay. Two to 3 pounds of cottonseed meal, 1 to 4 pounds of corn-and-cob meal, and 5 to 8 pounds each of cottonseed hulls and legume hay provide a satisfactory ration.

Beef cattle.—Begin now to feed mature beef animals.

Rations.—At the outset feed 2 pounds of cotton seed or cottonseed meal, 25 pounds of silage or its equivalent of cottonseed hulls and hay (1 pound of hay or hulls to 2 pounds of silage). Gradually increase this ration so that at the end of the feeding period (100 days) each animal is receiving 6 pounds of meal and 45 pounds of silage or the equivalent.

Horses.—Rations for young animals: One pound of grain and 2 pounds of hay for each 100 pounds of live weight. (1) Corn, 1 part; oats, 1 part; bran, 1 part; legume hay and stover, 1 part each. (2) Corn, 1 part; cottonseed meal, one-half part; bran, 1 part; and hay, 2 parts.

Rations for work horses: (1) Oats, 7 pounds; sorghum hay, 7 pounds. (2) Corn, 10 pounds; cottonseed meal, 2 pounds; and mixed hay, 14 pounds.

Class assignment.—Supplement the foregoing with notes from United States Department of Agriculture Buls. 73 and 110; Alabama Experiment Station Buls. 128, 150, and 158; Farmers' Bul. 580.

Practical exercises.—(1) Make a community survey of the breeds of beef animals. The survey should include the pure-bred animals, kinds of breeds, and number of each; grade animals, kinds of breeds, and number of each; and the number of scrubs. (2) An interesting project for boys is to have charge of a baby beef. Begin now to prepare it for market. To begin with, weigh it and start it on a half ration. Gradually increase the feed until the calf is on a full ration. Keep a daily record of the feed and a weekly record of the calf's weight.

Correlations.—Language: Prepare sheets for tabulating the facts secured by the survey and for keeping feed and weight records of the calf. Geography: Does the community raise its supply of mules and horses? If not, from what States do they come? Locate these States on the map. The proceeds of what crops are given in exchange for horses and mules? Arithmetic: Develop problems to determine the amount of money spent by the community each year for mules and horses.

LESSON EIGHT.

SUBJECT: GARDENING. TOPICS: COLD FRAME, SEASONAL PLANTING, COLLECTING AND PREPARING COMPOST FOR SPRING GARDEN.

Cold frame.—The site should have a southern exposure, should be well drained, and should have good, rich soil.

Seasonal planting.—Start in the cold frame lettuce, cabbage, and cauliflower. Set in the open sweet peas and all kinds of flowering bulbs.

Preparing compost.—Select a dry shed and begin collecting manure and preparing compost for the spring garden.

Class assignment.—Duggar's, pp. 185–188; Farmers' Buls. 185 and 218; Alabama Experiment Station Circ. 14, parts 1 and 2.

Practical exercises.—(1) Make a cold frame for the school grounds. Sow lettuce, cabbage, and cauliflower seeds. (2) Tomato-club girls should have compost heaps prepared for the next crop.

Correlations.—Language and drawing: Have each pupil write a description and make a drawing of the cold frame. Geography: Is there a nearby market for winter-grown vegetables? Compare the railroad and marketing advantages of the community with those of counties like Cullman, Sumter, Chilton, Conecuh, Escambia, Mobile, Montgomery, and Jefferson. Arithmetic: Find cost of the material in the cold frame. Find the area of the cold frame in square inches. How many plants may be started in this frame if 4 square inches are allowed to each plant?

DECEMBER.

LESSON ONE.

SUBJECT: SOILS. TOPIC: CROP ROTATION.

Purposes.—Improve the soil, get rid of weeds, avoid plant diseases and insect pests, provide suitable crops.

Kinds of crops.—Money crops, feed crops, soil-improving crops.

Class assignment.—Duggar's, pp. 116–122. See copy of soil survey of the county.

Practical exercises.—(1) Have pupils prepare and submit three-year and four-year rotation courses, keeping in mind community conditions and needs. Remember that enriching the soil is the ultimate purpose. (2) Visit a farm where a good system of rotation is practiced. Take notes.

Correlations.—Language: Written work is provided in writing out in good form the rotation courses. Drawing: Require the pupils to outline the home farm or the farm visited showing the divisions made for purposes of rotation. Indicate the crops grown the present year. Arithmetic: Develop problems on the value of rotation courses. See United States Department of Agriculture Bul. 132, p. 41.

LESSON TWO.

SUBJECT: CROPS. TOPIC: CORN JUDGING.

Subtopics.—Object of corn judging, use of score card, selecting good ears, arranging an exhibit.

Class assignment.—Duggar's, pp. 129–135. Supplement the lesson with notes from Farmers' Buls. 415 and 617.

Practical exercises.—See "Exercise" and "Note to teacher," Duggar's, p. 135.

Correlations.—Language: Require each corn-club member to submit a written report covering such points as cost of production, kinds of fertilizers, method of applying fertilizers, yields, value, exhibits made, and prizes won. Arithmetic: Select five choice ears and five ordinary ears. Weigh each lot in the ear. How many ears of each are required to produce a bushel of 70 pounds? Shell and weigh each lot. How many ears of each are required to make a bushel of 56 pounds?

LESSON THREE.

SUBJECT: FARM ANIMALS. TOPICS: TYPES AND BREEDS OF HORSES AND CATTLE.

Class assignment.—Duggar's, pp. 284–294. Supplement the lesson with notes from Farmers' Buls. 612 and 619.

Practical exercises.—(1) Gradually increase the feed to baby beeves. Keep a daily record of the feed weights and weekly record of the calf's weight. See that the calf is well housed at night and on

stormy days. (2) Pupils that have not baby beeves should assume the care of colts. Follow rations suggested the previous month. See that the colts are well housed at night and on stormy days. Begin handling the colts as much as possible. Get them accustomed to the halter so that they will lead and stand when tied. (3) Make a survey of the community as to the horses and mules. Determine the different breeds of horses, the number of pure-bred animals and the number of grades of each breed, the number of scrubs, and the number of mules.

Correlations.—Language: Keeping records of projects provides written work. Make sheets for tabulating the facts obtained in making the animal survey. Arithmetic: Find the number and value of the mules and horses of the community. Find the cost of feeding baby beeves for the month and the cost per pound of increase in weight. Determine the number and the value of the horses and mules in the community.

LESSON FOUR.

SUBJECT: DAIRYING. TOPIC: BUTTER MAKING.

Subtopics.—Ripening cream, starters, determining the ripeness of cream, churning, washing butter, salting butter, working, printing, and packing butter, and dairy equipment.

Class assignment.—Duggar's, pp. 326–329. Supplement the lesson with notes from Farmers' Buls. 349 and 541.

Practical exercises.—(1) Require a report from each pupil with reference to the method of butter making at the home. (2) If there is a commercial dairy in the community, visit it with the class to observe the equipment and the method employed in making butter. Take notes.

Correlations.—Language: Writing up reports and developing notes taken on the visit to the dairy furnish language work. Drawing: Vessels and equipment used in butter making provide materials for drawing exercises. Geography: In 1909 New York produced and sold \$77,807,161 worth of dairy products; Wisconsin, \$53,868,028; Iowa, \$31,196,883; and Alabama, \$6,396,198. Locate these States on the map. Compare the climatic and agricultural conditions of these States. Should Alabama buy dairy products from other States? Arithmetic: See "Problems," Duggar's, p. 329.

LESSON FIVE.

SUBJECT: POULTRY. TOPICS: (1) FATTENING AND MARKETING, (2) SELECTING THE BREEDING PENS.

Fattening.—Pen fattening, crate fattening, cramming, and feeds for fattening.

Marketing.—Killing, dressing, packing, and shipping live poultry.

Breeding pen.—Age, vigor, and relationship of the male; age, qualities, and number of hens.

Class assignment.—Give pupils notes from Farmers' Buls. 287, pp. 27-28, 36-38; 355, pp. 31-34.

Practical exercises.—(1) Poultry-club members should select their breeding pens and prepare for the work of the new year. (1) Let each member of the class take charge of a few fowls at home for the purpose of fattening them for the Christmas market. Try the different methods of fattening and report the results.

Correlations.—Language: Require club members to submit reports covering the results of the year's work with poultry. Have pupils write letters to poultry dealers asking for literature and prices. Arithmetic: Develop problems based on the reports of club members. See United States Department of Agriculture Bul. 132, p. 39, December.

LESSON SIX.

SUBJECT: SOILS. TOPIC: TERRACING AND DITCHING.

Terracing.—As soon as crops are removed and before winter rains set in, the old terraces should be built up and new ones laid out and thrown up.

Ditching.—Lands needing drainage, benefits from drainage, classes of drains.

Class assignment.—Duggar's, pp. 74-81. Supplement the lesson with notes from United States Department of Agriculture Bul. 91 and Farmers' Bul. 158.

Practical exercises.—(1) Have pupils secure materials and construct a triangular terrace level as described in Farmers' Bul. 158, pp. 15-16. (2) Make a trip with the class to a farm where tile drains are being laid. Observe the need of draining and the method employed. Take notes on the kinds and cost of materials used.

Correlations.—Language and drawing: Draw to scale and write an account of the materials used and the steps taken in constructing a terrace level. Arithmetic: Find the cost of the material used in constructing the terrace level. Develop problems on the cost of laying tile drains at the farm visited. See United States Department of Agriculture Bul. 132, p. 41, May exercises.

LESSON SEVEN.

SUBJECT: FARM ANIMALS. TOPIC: SAVING MEAT.

Dressing.—Killing, scalding, scraping, and cleaning.

Keeping.—Cooling the carcass and cutting.

Curing.—Vessels, preservatives, brine, and dry curing.

Recipes for special curing.—Salt pork, sugar-cured hams and bacon, dry-cured hams, headcheese, pickled feet, lard, and sausage.

Class assignment.—Give the class notes from Farmers' Buls. 183 and 391; Alabama Experiment Station Bul. 166.

Practical exercises.—(1) Pig-club members can get practice in dressing their own pigs. (2) Have pupils report in writing the practice at their homes as to dressing, keeping, and curing meat.

Correlations.—Language: Written work is provided in "Practical exercise 2." Arithmetic: Have pupils report weights of their butchered pigs. Find the total weight of meat produced in the community, the average amount per family, and the value of the total amount produced. See United States Department of Agriculture Bul. 132, p. 39, for exercises in arithmetic.

LESSON EIGHT.

SUBJECT: FARM IMPLEMENTS AND MACHINERY—ROADS.

Class assignment.—Duggar's, pp. 333-340. Supplement the lesson with notes from Farmers' Buls. 270, 347, and 597.

Practical exercises.—(1) The teacher should take the class to a farm well equipped with machinery or to a hardware store. Make lists of the various farm implements and note their uses. The teacher should secure the cooperation of the farmer or the hardware merchant in this work. Under the direction of the farmer or merchant take down and set up a rather complicated machine. (2) Secure the cooperation of the patrons and grade the school-ground walks. After grading the walks dress them with a layer of gravel, chert, shells, or cinders.

Correlations.—Language: Copy the list of farm implements in the class notebooks. Drawing: Outline a split-log drag. Geography: Locate on the county map the principal public highways. Locate on the State map the counties that have good roads. History: What has the county done for the improvement of roads? What system of keeping the roads in condition is in vogue? How have improved roads affected the price of land in the country? Arithmetic: Make a survey of the farm tools and implements in the community. Find their value. What was the amount of the road-bond issue in the county? How many miles of road were constructed? What was the average cost per mile? Find the cost of split-log and plank drags described in Farmers' Bul. 597.

JANUARY.

LESSON ONE.

SUBJECT: IMPROVING SOIL. TOPIC: MANURE MANAGEMENT.

Applying manure to the soil.—Methods: Placing in heaps about the field, broadcasting, applying in hill or drill with seed.

Storing manure.—Providing shed, packing, applying moisture.

Class assignment.—Duggar's, pp. 93-96. Supplement the lesson with notes from Farmers' Bul. 192.

Practical exercises.—(1) Require the members of the class to report the methods employed at their homes in the management of manure. (2) Club members should begin spreading manure on their plats.

Correlations.—Arithmetic: Keep a record of the amount and value of manure applied to the soil of garden or field projects.

LESSON TWO.

SUBJECT: CROPS. TOPIC: TESTING SEED CORN.

The vitality of the seed determines the regularity of the stand and the vigor of the plants, hence the importance of good seed. The vitality of seed may be determined by the appearance of the kernel and by the germinating test.

Class assignment.—Duggar's, pp. 130-132. Supplement the lesson with notes from Farmers' Buls. 253, 415, 428, 537, and 617.

Practical exercises.—(1) Make and equip a germinating box as described in Farmers' Bul. 253, p. 8. Conduct a germinating test at school, using selected seed corn. (2) Each club member should test his seed corn this month.

Correlations.—Language and drawing: Describe and draw to scale the germinating box. Arithmetic: Develop problems based on the results of the germinating test showing the possible loss in yield sustained by those who do not test seed. See United States Department of Agriculture Bul. 132.

LESSON THREE.

SUBJECT: HOME GARDEN. TOPICS: (1) MAKING THE HOTBED; (2) PREPARING THE GARDEN.

The hotbed.—Selecting site, preparing manure, making frame and excavation, making hotbed, sowing seed.

Preparing the garden.—Spreading compost, breaking soil and preparing seed bed, compounding fertilizers.

Class assignment.—Duggar's, pp. 185-191. Supplement with notes from Farmers' Bul. 255 and Alabama Experiment Station Circ. 14, Parts I and II.

Practical exercises.—(1) Make a hotbed for the school. (2) Club members should make hotbeds at their homes. Compost should be spread over the plats and the soil plowed thoroughly.

Correlations.—Language: Write an account of the steps taken in making a hotbed. Drawing: Have each pupil draw to scale the home garden and the school garden. Arithmetic: Find the cost of making a hotbed, taking into account labor, lumber, and manure. If plants stand $1\frac{1}{2}$ inches apart each way, how many can be started in the school hotbed? Find the areas of the home and school gardens in the drawing exercises.

LESSON FOUR.

SUBJECT: DAIRYING. TOPIC: BREEDS.

Class assignment.—Duggar's, pp. 295–298. Supplement the lesson with notes from Farmers' Bul. 106.

Practical exercises.—Make a survey of the community as to the breeds of dairy cattle and the number of animals of each breed. Let the records show the number of pure-bred animals of each breed, the number of grades of each breed, and the number of "scrubs." Have the pupils secure this information from their homes and from the homes of their immediate neighbors. Where possible secure the estimated value of each animal.

Correlations.—Language: Tabulating the facts obtained in the foregoing survey provides written work. Geography: Make a map of the community and locate thereon the homes of farmers who own pure-bred dairy cows. History: Have members of the class prepare a written account covering these points—the dates when the different breeds were introduced into the community, the extent each breed has been used, and the comparative value of each breed. Arithmetic: Develop problems to determine the number of pure-bred animals, the number of grades and the number of scrubs, the fractional part the pure breeds, the grades, and the scrubs each is to the whole number of cattle; the percentage in each case. Find the value of the different breeds and of all the dairy cattle in the community.

LESSON FIVE.

SUBJECT: SOIL. TOPIC: CONSERVING SOIL MOISTURE.

How to secure and retain a supply of soil moisture sufficient to produce an abundant crop is one of the important problems of the farmer. As a result of the winter rains a supply of moisture should be accumulating, hence the necessity of studying the relation of water to the soil.

Class assignment.—Duggar's, pp. 65–69.

Practical exercises.—(1) Perform the exercises suggested in the text in connection with this lesson. Also see exercises in Farmers' Bul. 218.

Correlations.—Language: Have pupils take notes in connection with the practical exercises. Write them up in full and copy in the notebook. Arithmetic: Develop problems based on results of the experiments to determine the weight of water in different areas of soil, taking into account the depth of breaking the land.

LESSON SIX.

SUBJECT: POULTRY. TOPICS: (1) CARE OF BREEDING HENS; (2) EGGS FOR INCUBATION.

Care of breeding hens.—Care during the mating season and feed for breeding hens.

Eggs for incubation.—Collecting, selecting, and keeping.

Class assignment.—Give the class notes covering the foregoing outline from Farmers' Buls. 287 and 562.

Practical exercises.—(1) Members of the poultry club should follow carefully the foregoing instructions as they apply to the work of feeding and caring for hens, and collecting, selecting, and keeping eggs. (2) Those members that mean to start their project with eggs should decide on a breed and place an order for eggs. (3) Each member should be provided with an egg tester as described in Farmers' Bul. 562. (4) Keep records of the daily rations fed and the eggs collected.

Correlations.—Language: Provide tables for keeping records of feeding rations and eggs collected. Arithmetic: Develop problems on the cost of feeding the club members' flocks or flocks at the homes of the pupils; also on the value of eggs produced for incubation. Based on the number produced and the cost of the care of the hens, what do the eggs cost per dozen?

LESSON SEVEN.

SUBJECT: FARM ANIMALS. TOPICS: (1) BREED OF HOGS; (2) SELECTING BROOD SOW.

Class assignment.—Breeds: Duggar's, pp. 303–305. Selecting brood sow: Cover this topic with notes from Farmers' Buls. 205 and 566.

Practical exercises.—(1) Pig-club members should select and breed their sows this month. (2) Members who assume responsibility for only one pig should arrange to secure a pure-bred animal. For instructions as to managing the pig see Farmers' Bul. 566 and Alabama Experiment Station Bul. 168. (3) Make a community hog survey. Determine the number of pure-bred animals of each breed, the number of grades of each breed, and the number of scrubs.

Correlations.—Language: Prepare tables for collecting and tabulating the facts with reference to the hog survey. Geography: Fill in on the community maps used for locating dairy cattle the homes where pure-bred hogs are kept. History: Have the pupils prepare accounts in connection with the several breeds as to the dates of introduction, the extent to which grown, and the comparative success of each. Arithmetic: Develop problems to determine the number and value of the different breeds, the whole number and value of the hogs in the community, and the percentage of pure-bred hogs.

LESSON EIGHT.

SUBJECT: PLANTS. TOPIC: PROPAGATION.

Subtopics.—(1) Methods: By seed, by parts of plants. (2) Parts of plants: Cuttings, grafts. (3) Kinds of grafts and directions for grafting.

Class assignment.—Duggar's, pp. 38-45. Supplement the lesson with notes from Farmers' Buls. 157 and 218.

Practical exercises.—(1) Have the pupils practice making whip and cleft grafts, as shown on page 42 of Duggar's. Use small twigs and limbs of plum trees, persimmon trees, apple trees, and the like. (2) After pupils have become proficient in making grafts have them make permanent grafts. (3) Make cuttings of grapes and shrubbery and set them on the school ground. (4) Practice making grafting wax. See Duggar's, p. 45.

Correlations.—Language and drawing: Write descriptions and make sketches of grafts made. Arithmetic: Develop problems on the cost of materials required to make given amounts of grafting wax.

FEBRUARY.

LESSON ONE.

SUBJECT: FERTILIZERS. TOPIC: ESSENTIAL ELEMENTS.

Subtopics.—Nitrogen, phosphoric acid, potash, and lime—their sources.

Class assignment.—Duggar's, pp. 97-101. Supplement the lesson with notes from Farmers' Buls. 44 and 398.

Practical exercises.—See "Exercise" and "Note to the teacher," Duggar's, p. 101.

Correlations.—Geography: Sodium nitrate comes from Chile, South America; kainit from Germany; phosphate rock from South Carolina, Tennessee, and Florida; dried blood and tankage from the great packing houses, such as those located at Chicago, Omaha, Kansas City, and Dallas. Locate these on the map and trace the routes of travel from your community to these countries, States, and cities.

LESSON TWO.

SUBJECT: FERTILIZERS. TOPICS: (1) CALCULATING FORMULAS; (2) HOME MIXING.

Calculating formulas.—Interpreting formulas, finding the commercial value.

Home mixing.—Advantages, fillers.

Class assignment.—Duggar's, pp. 102–107, and Appendix, p. 1.

Practical exercises.—(1) Club members should compound their fertilizers. If it is convenient, take the class to the home of some club member or some farmer who is mixing fertilizers and give the pupils practice in this work. (2) Have members of the class report the brands and formulas of fertilizers used at their homes, also the purpose for which each is used.

Correlations.—Arithmetic: See "Problems" in Duggar's, p. 107; Farmers' Bul. 44, p. 14; United States Department of Agriculture Bul. 132.

LESSON THREE.

SUBJECT: FERTILIZERS. TOPIC: SUITING FERTILIZERS TO SOILS AND CROPS.

Class assignment.—Duggar's, pp. 108–111; also Appendix, pp. I and II. Supplement the lesson with notes from Farmers' Buls. 44 and 398.

Practical exercises.—(1) Have the members of the class report the special formulas or brands used at their homes for corn, cotton, Irish potatoes, oats, and vegetables. Compare the percentages of essential elements in each case and explain why different formulas are used for different crops. (2) Compare the formulas reported by the pupils with those recommended in the textbook and in Farmers' Bul. 398.

Correlations.—Language: Have the members of the class copy in their notebooks all the reports in practical exercise 1. Arithmetic: Continue the work as suggested in the previous lesson.

LESSON FOUR.

SUBJECT: HOME ORCHARD. TOPICS: (1) PLANTING AND TRAINING YOUNG GRAPE VINES; (2) PRUNING AND TRAINING BEARING VINES.

Young vines.—Making cuttings, grafting, planting cuttings or rooted vines, first pruning, summer pruning.

Bearing vines.—Principles, objects, and methods of pruning; training, the trellis; pruning implements.

Class assignment.—Give to the class as notes material found in Farmers' Buls. 471, pp. 12–16; 181, pp. 22, 23, and 30–32.

Practical exercises.—(1) Make a trip with the class to a good orchard to observe practice in pruning. Make previous engagement

with the farmer. (2) Have the pupils bring grape canes from their homes and give them practice in making and setting cuttings. If vines are growing on the school grounds, follow directions found in Farmers' Bul. 471 in pruning and training.

Correlations.—Language and drawing: Have the pupils write descriptions and make sketches of cuttings, properly pruned vines, and trellises for training. Arithmetic: Develop problems on the cost of trellising 100 vines by different methods.

LESSON FIVE.

SUBJECT: HOME ORCHARD. TOPIC: PRUNING TREES.

Subtopics.—Pruning at the time of planting; shaping the young tree; later pruning; fruits that most need pruning; implements; after treatment.

Class assignment.—Duggar's, pp. 221–224. Supplement with notes from Farmers' Buls. 181 and 491.

Practical exercises.—(1) If practicable, take the members of the class to a near-by orchard to observe practice in pruning. (2) Have pupils submit written reports on the methods of pruning practiced at their homes. (3) Club work or a home project with a few fruit trees is desirable, especially in sections where fruit growing is an important industry. For instructions write to the Alabama Polytechnic Institute, Auburn, Ala., or the Department of Agriculture, Washington, D. C.

Correlations.—Language and drawing: Make a drawing and tell how to make a proper cut. Make drawings of pruning implements. Have pupils copy in the class notebooks the reports on pruning. Geography: What States lead in the production of apples, peaches, and oranges? Locate these States on the map. What effect has climate on the production of these fruits as indicated by the sections in which they succeed best?

LESSON SIX.

SUBJECT: HOME ORCHARD. TOPIC: (1) SPRAYING; (2) CULTIVATION AND FERTILIZATION.

Spraying.—San José scale, peach curl, brown rot, fire blight, apple scab; materials, equipment.

Cultivation and fertilization.—Plowing the soil, applying fertilizers (12:2:8) liberally, thorough harrowing.

Class assignment.—Duggar's, pp. 229–232; Appendix, pp. III and IV; pp. 217. Supplement with notes from Farmers' Bul. 243; Alabama Experiment Station Buls. 144 and 156.

Practical exercises.—(1) If practicable take the members of the class to a near-by orchard to observe practice in spraying. (2) Re-

quire members of the class to make written reports on the spraying at their homes covering such phases as the formulas of spraying materials used, the spraying machinery, the fruits sprayed, and the diseases or insects combated. (3) Fruit-club or home-project members should spray, cultivate, and fertilize their trees.

Correlations.—Language and drawing: Describe and make sketch of a barrel spray. History: Have pupils write accounts of the introduction and spread of damage done by fruit diseases found in the community. Arithmetic: Develop problems on the cost of sprays. See United States Department of Agriculture Bul. 132.

LESSON SEVEN.

SUBJECT: HOME GARDEN. TOPIC: PLANTING IN HOTBEDS AND IN THE OPEN.

Hotbeds.—These should be given constant attention to prevent overheating and to secure ventilation. Tomato, eggplant, and pepper seeds should be sown in the hotbed about the middle of the month. Melon plants should be started in boxes in the southern part of the State. Plants from seeds sown in January should be ready to transfer to the cold frame, and after being hardened off set in the open.

Planting in the open.—Winter rains have leached much of the available fertility from garden soils, hence it is necessary to apply well-rotted manure or high-grade fertilizers, preferably both. Apply an 8:2:8 high-grade fertilizer at the rate of 500 to 1,000 pounds per acre.

Irish potatoes, cabbage, onions, radishes, lettuce, spinach, turnips, carrots, and English peas should be planted this month. Soak seed potatoes for two hours in a formalin solution (40 per cent formaldehyde) consisting of 1 ounce of formalin and 2 gallons of water.

Class assignment.—Duggar's, pp. 185-191. Supplement the lesson with notes from Alabama Experiment Station Circ. 14, Parts I and II; Farmer's Buls. 220, 255, 354, 433, 434, and 544.

Practical exercises.—(1) Prepare the soil and begin planting vegetables on the school or home gardens. The pupils should plant such vegetables as potatoes, onions, lettuce, turnips, radishes, and peas. (2) Club members should plant tomato seed either in hotbeds or boxes. Plow and harrow the soil that is to be used for the tomato plat. Well-rotted manure should be applied before the soil is harrowed.

Correlations.—Language: Have the members of the class make written reports of the work done this month in their gardens. Those who do not have plats of their own should be required to report on the work done in the home gardens. Arithmetic: From the reports made by the pupils of the class develop problems to determine the cost of the gardens this month, taking into account labor, fertilizer, and seed.

LESSON EIGHT.

SUBJECT: POULTRY. TOPIC: INCUBATION.

Natural incubation.—The hen, how to set the hen, care of the sitting hen.

Artificial incubation.—Types of incubators, selecting the incubator, locating the incubator, the temperature to maintain, care of the lamp, turning and cooling the eggs, care of machine at hatching time.

Class assignment.—The foregoing outline is based largely on Farmers' Bul. 585. Let the teacher secure a copy of this bulletin and give the class notes on the foregoing phases of the subject. Supplement these notes with reading exercises from farm papers. See also Farmers' Bul. 287.

Practical exercises.—(1) Club members or pupils that have projects with poultry should make plans and set one or more hens this month. If the pupil has charge of a large flock of hens it might be advisable to invest in an incubator. Get the work of incubation started this month. Keep exact records as to dates, eggs used, and other features of incubation. (2) Require pupils that have no projects with poultry to make observations at their homes and submit written reports covering such points as the number of hens being set, the number of eggs under each, the kind of nests used, and the care of the hens. If incubators are used at any of these pupils' homes, have the pupils report on the following points: The kind, capacity, and location of the incubator; the temperature maintained, and the attention given the eggs.

Correlations.—Language: Club members and others having projects with poultry should prepare tables for keeping records in connection with this incubating work. Written reports provide additional language work.

MARCH.

LESSON ONE.

SUBJECT: SOIL. TOPIC: PREPARING SEED BED.

Subtopics.—Breaking, harrowing, dragging, or rolling.

Class assignment.—Duggar's, pp. 70-72. Supplement the lesson with notes from Farmers' Buls. 81, 537, and 601.

Practical exercises.—(1) Have members of the class submit a list of implements used in plowing, harrowing, dragging, or rolling the land at their homes. Also have them report whether the land was plowed in the fall or winter, whether it grew a cover crop, or whether it is unplowed stubble or stalk land. (2) If practicable accompany the pupils of the class to a near-by field where good work is being done in the way of preparing the seed bed. Take notes on the implements used in plowing, harrowing, rolling, or dragging.

Correlations.—Language: The pupils' reports provide written exercises. Drawing: Have pupils make a sketch of a turn plow, locating the parts—namely, handles, beams, share, moldboard, and land-slide. History: Have some member of the class prepare and read a statement giving an account of the community methods that have been and are now employed in turning land, including the kinds of plows used. Let this statement date as far back as reliable information may be secured. Arithmetic: Develop problems showing the economy in using large plows instead of small ones in turning land. A man with a 2-horse plow can turn 2 acres per day at a cost of \$2.50. A man with a 1-horse plow can turn 1 acre per day at a cost of \$2. Find the difference in cost in breaking fields of 10, 20, and 30 acres.

LESSON TWO.

SUBJECT: POULTRY. TOPIC: BROODING.

Natural brooding.—The hen, the coop, handling the chicks, feeding, keeping down lice, protecting from enemies.

Artificial brooding.—The brooder, testing the brooder, removing chicks from the incubator to the brooder, teaching chicks to find heat, regulating the temperature, feeding. Fireless brooders—location, teaching chicks to keep warm.

Class assignment.—The teacher should read carefully Farmers' Bul. 624 and give the class notes covering the foregoing outline. See also Farmers' Buls. 287 and 585.

Practical exercises.—(1) Club members should provide brood coops for their hens and chicks. See page 13, Farmers' Bul. 574, and page 4, Farmers' Bul. 624. If artificial brooding is practiced, see pages 8 and 10, Farmers' Bul. 624. (2) Require pupils that have no projects with poultry to submit written reports as to the kinds of brooding coops used with hens, and in case of artificial brooding the reports should cover descriptions of the brooders used. Successes and failures in brooding should be noted and accounted for.

Correlations.—Language and drawing: Have pupils write descriptions and make drawings of the brooding coops used in connection with poultry projects or used at their homes. Arithmetic: Find the cost in labor and materials of the several brooders and brooding coops reported. How many broilers at the prevailing price would be necessary to cover the cost of each brooding coop? Does it appear to be economical to provide good coops?

LESSON THREE.

SUBJECT: FARM ANIMALS. TOPIC: GRAZING CROPS FOR HOGS.

Temporary.—The accompanying table suggests a series of grazing crops that provide hog pasturage for almost the entire year. A selec-

tion adapted to local conditions should be made and preparations begun to provide continuous pasturage for the hogs.

Grazing crops for hogs.

Crop.	When planted.	How planted—seed per acre.	Grazing period.
Melilotus on lime lands.	February and March.	Broadcast, 10 to 20 pounds; add $\frac{1}{2}$ if unhulled.	60 days after seeding; at any season when growing.
Cowpeas.....	May 1 to July 1	$1\frac{1}{2}$ bushels seed broadcast; $\frac{1}{2}$ bushel in drills.	75 to 90 days after seeding; lasts from 30 to 60 days.
Soy beans.....	do.....	$1\frac{1}{2}$ bushels seed broadcast; $\frac{1}{2}$ bushel in drills.	90 to 100 days after seeding; lasts from 30 to 90 days.
Velvet beans...	Apr. 1 to May 15.	$\frac{1}{2}$ to $3\frac{1}{4}$ pecks in drills.....	150 to 180 days after seeding; after frost; lasts all winter.
Peanuts, Spanish.	May 1 to July 1	1 to 2 bushels, not hulled, in drills.	100 to 120 days after seeding; lasts 60 to 90 days.
Lespedeza.....	March and April.	1 bushel or 24 pounds seed, broadcast.	75 to 90 days after seeding; grazed any time during warm weather or while growing.
Sorghum.....	Apr. 15 to July 1.	Broadcast, 1 to 2 bushels seed; drill 1 to 2 pecks.	60 to 90 days after seeding; lasts 30 to 60 days.
Chufas.....	Mar. 15 to June 1.	3 to 4 pecks in rows.....	130 to 150 days after planting; lasts all winter.
Sweet potatoes.	Plants set in May.	7,000 to 9,000 plants, 3-foot rows, $1\frac{1}{2}$ to 2 feet in row.	100 to 150 days after planting; lasts 60 to 90 days.
Rape.....	Feb. 1 to Mar. 10.	In rows, 3 to 4 pounds seed; broadcast, 6 to 8 pounds seed.	50 to 65 days after seeding; fall seeding; lasts all winter; spring seeding until May 15.

Permanent.—Bermuda and bur clover. Set Bermuda in the spring; seed bur clover in August.

Class assignment.—Duggar's, pp. 162, 165, 174, 178, and 180. Give the class notes from Farmers' Bul. 411, pp. 22–33; Alabama Experiment Station Bul. 168.

Practical exercises.—(1) Pig-club members should make preparations for spring, summer, and fall hog pastures. Make selections from crops mentioned in this lesson and plan to have green feed during the entire year. (2) Have all members of the class report in writing as to the permanent pastures at their homes covering such points as the kinds, the number of acres in each, and the success with which grown. (3) Review the September lesson on Sow and Pig Management.

Correlations.—Language: The written reports required in the practical exercises provide language work. Drawing: Have the pupils secure dimensions and draw to scale the permanent pastures at their homes. Show the location of streams, shades, and the like. Arithmetic: Find the area in acres of the several pastures reported. Estimate the average number of hogs to each pasture and find the pasturage area for each hog.

LESSON FOUR.

SUBJECT: INSECTS AND HEALTH. TOPICS: (1) FLIES; MOSQUITOES.

Flies.—Life history, carriers of disease, remedies and preventives.

Mosquitoes.—Important kinds, how to recognize the malarial and yellow fever mosquitoes, how disease is spread by mosquitoes, protection and remedies.

Class assignment.—Duggar's, pp. 272–276. Supplement the lesson with notes from Farmers' Buls. 444, 459, and 463; Alabama Press Buls. 55 and 56.

Practical exercises.—(1) Bring to school a bottle or can of water containing wrigglers (wiggle tails) and cover the surface of the water with a layer of oil. Study developments and take notes. (2) Drain all pools about the home or the school, remove all discarded vessels, and screen water barrels and tanks. (3) Secure and bring to school in a closed vessel some material containing eggs or larvæ of flies. Examine carefully each day and take notes on the developments. (4) Make a fly trap by instructions found in Alabama Press Bul. 56.

Correlations.—Language and drawing: Write an account of the life history of the fly and make drawings of each stage. Make a drawing of a malaria mosquito at rest. Arithmetic: A female fly that survives the winter lays four batches of 120 eggs each. Sixty eggs of each batch produce female flies. They in turn lay four batches of 120 eggs each of which 60 produce female flies. Reproduction continues at this rate through 12 generations in a season. Find the number of flies produced in the twelfth generation. Emphasize the importance of destroying flies in March.

LESSON FIVE.

SUBJECT: INSECTS. TOPICS: (1) INSECT DEFINED; (2) INSECT GROWTH; (3) HOW INSECTS FEED.

Insects defined.—What is an insect? The principal parts.

Insect growth.—Insects developing without much change, stages in an insect's life, transformation from caterpillar to butterfly.

How insects feed.—Biting and sucking.

Class assignment.—Duggar's, pp. 246–256. Supplement with notes from Farmers' Bul. 127 and Alabama Experiment Station Bul. 139.

Practical exercises.—(1) Look for adult boll weevils, peach borers, plum curculios, and potato beetles. Make and mount a collection of insects this month. See Farmers' Bul. 606. (2) Club members should examine carefully their vegetables and plan to combat insect attacks.

Correlations.—Language and drawing: Describe and draw the several insects collected and mounted. History: Have each pupil of the class write an account of each insect as to date of introduction into the community, damage done, spread, and methods of combating. Arithmetic: Develop problems to determine damage done by insects the previous year based on community estimates.

LESSON SIX.

SUBJECT: HORTICULTURE. TOPICS: (1) SPRAYING CONTINUED; (2) GARDENING.

Spraying.—Continue spraying for San José scale, peach leaf curl, brown rot, and apple scab. See February lesson on spraying.

Spray apples, pears, and quinces for codling moth; plums and peaches for curculio and rot; grapes for anthracnose, mildew, and rot. For codling moth use 1 pound of dry arsenate of lead to 50 gallons of water, with an addition of 2 pounds of lime to make a white spray. The same spray should be used for the curculio. Spray grapes with Bordeaux mixture.

Gardening.—Transplant peppers and cabbage. In the southern part of the State set eggplants. Bed sweet potatoes. Plant in the open bush beans, Lima beans, cucumbers, okra, parsnips, and salsify.

Class assignment.—Duggar's, pp. 258-260, 229-232, 185, 186, and 190. Supplement the lesson on sprays with notes from Alabama Experiment Station Buls. 139 and 144; Circ. 1; Farmers' Buls. 284, 440, and 492. Supplement the lesson on gardening with timely notes from Alabama Experiment Station Circ. 14, Parts I and II; Farmers' Buls. 232, 255, and 289.

Practical exercises.—(1) Continue the garden work on the school or home plats (2) Tomato club members should keep their plats thoroughly plowed and harrowed. Break up all clods and keep down the growth of weeds. (3) Pupils that have no projects and are not club members should be required to make written reports covering such points as the vegetables being planted at their homes, from what they are reproduced, whether from seed, bulbs or tubers, and how planted, whether in drills or on beds.

Correlations.—Language: Reports on work with home or school garden plats and work being done in the gardens at the homes of the pupils provide suitable written work. Each pupil should be required to copy all such reports in the notebooks. Arithmetic: Based upon the foregoing reports develop problems in connection with the garden work of the month. Labor, seed, and fertilizers should be taken into account.

LESSON SEVEN.

SUBJECT: SMALL FRUIT. TOPIC: SETTING STAWBERRIES.

Planting.—Soil should have abundant humus and be supplied with well-rotted manure; preparation should include thorough fall breaking and spring harrowing; plants should stand 2 feet apart, roots should be well pruned, and the soil should be packed firmly about them; crowns should not be covered.

Varieties.—Excelsior for early berries, Klondyke and Lady Thompson for medium, Aroma for late.

Fertilizers.—Apply at the rate 500 to 1,000 pounds of 12:2:10 formula per acre.

Class assignment.—Duggar's, pp. 217–219. Supplement the lesson with notes from Farmers' Buls. 198 and 664.

Practical exercises.—(1) A tenth of an acre of strawberries is recommended for a permanent home project. Each member of the class should be encouraged to assume responsibility for such a plat at his or her own home. (2) Secure written reports from the members of the class covering such points as the varieties of strawberries grown at their homes, the variety or varieties that have proved most successful, when planted, and how.

Correlations.—Language: Each pupil should be required to make a nice copy of the foregoing report. Geography: The counties of Baldwin, Chilton, Conecuh, Cullman, Escambia, Mobile, and Sumter are among the leading in the production of strawberries. Locate these on the map. What conditions make it possible for these counties to engage in the strawberry industry?

LESSON EIGHT.

SUBJECT: SOIL. TOPICS: (1) GERM LIFE IN THE SOIL; (2) SOME LEGUMINOUS CROPS.

Germ life in the soil.—Germs that help, aiding the germ friends, germ enemies, adding germs to the soil.

Some leguminous crops.—Alfalfa, red clover, Japan clover.

Class assignment.—Duggar's, pp. 244, 245, 168–172, 176–178. Supplement the lesson with notes from Farmers' Buls. 339, 441, and 455.

Practical exercises.—(1) Make a list of all the leguminous plants that are grown in the community. (2) Have members of the class bring to school leguminous plants found at their homes. Study stems and leaves to be able to recognize each plant at sight.

Correlations.—Geography: Japan clover (*lespedeza*) is so named as it is thought to have been introduced into this country from Japan. Locate Japan on the map. Compare it with Alabama as to latitude, longitude, climate, area, and agricultural productions.

APRIL.

LESSON ONE.

SUBJECT: POULTRY. TOPICS: (1) DISEASES; (2) PRESERVING EGGS.

Diseases.—Gapeworms, sorehead, fowl cholera, lice, crop bound—causes, symptoms, and treatment.

Preserving eggs.—Eggs to be stored, testing; preserving materials—water glass, lime water, salt, and bran.

Class assignment.—Give the pupils notes from Farmers' Buls. 287 and 530.

Practical exercises.—(1) Each club member should separate the male from the hens that are to produce eggs for market. As soon as the price of eggs reaches a point that is not profitable prepare to preserve the eggs for late fall and winter marketing. Follow instructions in Farmers' Bul. No. 287. (2) Have the members of the class make reports as to symptoms of diseased chickens at their homes. Compare these with the symptoms found in connection with the diseases studied.

Correlations.—Language: During this month each pupil of the class should be required to report weekly on the following facts at his home: The whole number of eggs laid, the number of eggs sold, the price received, the manner of disposing of the eggs—to local buyer or by parcel post. Arithmetic: From the foregoing facts develop problems adapted to needs of the class.

LESSON TWO.

SUBJECT: CROPS. TOPICS: PLANTING AND CULTIVATING CORN AND COTTON.

Subtopics.—Kinds of seed beds, distance between plants, fertilization, cultivation.

Class assignment.—Duggar's, pp. 125-127, 151-153. Supplement the lesson with notes from Farmers' Buls. 364, pp. 10-15; 537, pp. 14-15; 601.

Practical exercises.—(1) Club members should be preparing the land and planting their plats of corn and cotton. (2) Have the members of the class report the different methods employed in planting corn and cotton at their homes. (3) What is meant by a water furrow? A balk? A bed?

Correlations.—Language: Written work is provided for by the reports on planting methods required in practical exercises. Arithmetic: Have club members report the labor, fertilizers, and seed required to plant their plats of corn or cotton. From these facts develop problems to meet the needs of the class. History: The Indians planted corn when the leaves of oak trees were as large as a squirrel's ear. How does the present practice in your community compare with that of the Indians? Why is Indian corn so called?

LESSON THREE.

SUBJECT: HONEYBEES. TOPICS: HABITS, WORK, AND MANAGEMENT OF BEES.

Class assignment.—Duggar's, pp. 277-280. Supplement the lesson with notes from Farmers' Bul. 447. (These are important topics, and it may be necessary to make two lessons to treat them properly.)

Practical exercises.—(1) Go with the class to a home where bees are kept. Observe them and take notes on their movements. (2) Secure some honeycomb. Look for cells prepared for storing honey and those for rearing young bees. (3) The care and management of a few hives of bees provide an excellent project.

Correlations.—Language and drawing: Write a description and make a drawing of the type of hives used in the community.

LESSON FOUR.

SUBJECT: CROPS. TOPIC: HOW PLANTS FEED.

Food from the soil.—The plant food in the soil must be dissolved in water before it can be taken up by the roots and used by the plant. There are at least 10 elements of plant food taken from the soil, but the most important are nitrogen, phosphorus, potash, and calcium (lime).

Food from the air.—Plants take food from the air through tiny openings in the underside of the leaf. Carbon is the only element of plant food taken from the air, but it unites with water to make starch, which constitutes the great bulk of the plant.

Class assignment.—Duggar's, pp. 32-37. Supplement the lesson with notes from Farmers' Bul. 218, pp. 12-15.

Practical exercises.—(1) See "Experiment" and "Exercise," Duggar's, p. 36. (2) See "Exercises 3, 4, and 5," Farmers' Bul. 218, p. 14. (3) Club members should take an active interest in these exercises to learn fully the relations between their crops and the soil and air.

LESSON FIVE.

SUBJECT: CROPS. TOPIC: PREPARING FOR SILAGE.

Why silage should be made.—Best and cheapest form of succulent food; a very palatable food; a substitute for pastures during winter months.

Silage crops.—Corn, sorghums, cowpeas, soy beans, clover.

Harvesting the crops.—Time, equipment.

Making silage.—Cutting, packing, moistening, covering.

Class assignment.—Duggar's, pp. 124, 126, 174, 178, and 180. The teacher should give the class notes from Farmers' Bul. 578 covering the foregoing outline. This lesson is of special importance in stock-raising and dairy sections of Alabama.

Practical exercises.—(1) If there is a silo in the community, take the pupils of the class to visit it. If possible, secure from the owner the following information: Crops used in making silage, the length of the particles of silage, the time of making silage, and the manner of filling the silo. Require the pupils to take notes on the foregoing

points. (2) If there is a silo at the home of any member of the class require that pupil to make a written report covering the points mentioned in exercise 1.

Correlations.—Language: Require the pupils to copy in their booklets the notes and reports on the foregoing exercises. Arithmetic: (1) One cow consumes the silage from 8 square feet of surface to a depth of 2 inches each day. What should be the diameter of a silo to feed a herd of 10 cows? Fifteen cows? Twenty cows? (2) If the silage is fed an average depth of 2 inches each day, what should be the height of a silo to feed a herd 120 days? One hundred and eighty days? (3) If silage weighs an average of 35 pounds a cubic foot, how many tons in a silo 14 feet in diameter and 30 feet high?

LESSON SIX.

SUBJECT: HOME ORCHARD AND GARDEN. TOPICS: (1) CULTIVATING THE ORCHARD;
(2) PLANTING AND CULTIVATING THE GARDEN.

The orchard.—Plowing; fertilizing; planting low-growing, inter-cultural crops.

The garden.—Transplant sweet potatoes, eggplants, cantaloups, and make preparations to set tomatoes in May. Plant squash and pumpkin seeds. Continue planting beans and setting cabbage plants.

Class assignment.—Duggar's, pp. 216–217, 190, 162, 163, 164. Supplement the lesson with notes from Alabama Experiment Station Circ. 14, Part I, pp. 19, 29, and 36; Part II, pp. 68, 70, 72, and 73; Bul. 156, pp. 121, 122; Farmers' Buls. 491, 632, 642, and 647.

Practical exercises.—(1) Continue planting vegetables in the home and school gardens. (2) Tomato-club members should prepare to set tomato plants in May. The tomato plants should now be transferred from boxes or hotbeds to cold frames.

Correlations.—Drawing: Make a plan of the home garden, showing the location of the different kinds of vegetables. Arithmetic: Develop problems to determine the cost of labor, fertilizers, and seeds used this month in the school and home gardens.

LESSON SEVEN.

SUBJECT: FLOWERS. TOPICS: (1) IMPORTANCE; (2) PARTS; (3) POLLINATION.

Importance.—Plants produce flowers; flowers develop into seed; seed develop into plants.

Parts of flowers.—(1) Calyx, the divisions of which are called sepals; (2) corolla, the divisions of which are called petals; (3) stamens, the divisions of which are the filament, the anther, and the pollen; (4) pistil, the divisions of which are the ovary containing the ovules, the style, and the stigma.

Essential parts of the flower.—The stamen and the pistil with their divisions. They produce seed.

Pollination.—(1) Ripened pollen grains when shed by the anther either fall upon or are carried to the stigma of the pistil. The pollen grain produces a thread-like growth, which passes through the style into the ovary, where it gives off a cell to unite with an ovule. This union develops a seed. (2) Kinds of pollination: (a) Self-pollination, (b) cross-pollination. The latter is accomplished by winds and insects.

Class assignment.—Duggar's, pp. 7–20. (Omit paragraphs that are not essential.)

Practical exercises.—Have the pupils bring to school for study flowers of turnips, peaches, apples, strawberries, honeysuckles, and dogwood. Learn to name the principal parts. Which of these flowers are visited by insects?

Correlations.—Language and drawing: Have each member of the class describe and make drawings of one or more of the flowers studied.

LESSON EIGHT.

SUBJECT: WEEDS. TOPICS: (1) THE INJURY WEEDS DO; (2) KINDS AND HABITS; (3) METHODS OF COMBATING.

The injury weeds do.—They use plant food, take up moisture, make cultivation expensive.

Kinds and habits.—Annuals, biennials, perennials.

Methods of combating.—Uprooting, cutting off tops to prevent seeding, smothering, selecting clean seed.

Class assignment.—Duggar's, pp. 182–184. Supplement the lesson with notes from Farmers' Bul. 660.

Practical exercises.—Have the pupils bring to school for study specimens of all weeds that may be found in the gardens, orchard, or fields at this time. Learn to name them and list the names with a brief description in the class notebook. Those that can not be identified should be sent to the Alabama Polytechnic Institute, Auburn, Ala., for classification.

Correlations.—Language and drawing: Make written descriptions and drawings of the weeds studied. History: Require the pupils to prepare an account covering the following points with reference to the most injurious weeds found in the community: The dates of introduction, the spread, the damage done, and the methods of combating.



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(PROFESSIONAL PAPER.)

STUDIES ON CHANGES IN THE DEGREE OF OXIDATION OF ARSENIC IN ARSENICAL DIPPING BATHS.

BY ROBERT M. CHAPIN, *Senior Biochemist, Biochemic Division.*

INTRODUCTORY.

In the approximately four years during which arsenical dipping baths have been extensively employed for eradicating the Texas-fever tick in this country, and in the even longer period during which they have been put to similar use abroad, it has been discovered, along with other interesting and important facts, that the arsenic in such baths is prone to change its degree of oxidation. Arsenic is one of the considerable number of chemical elements which may be said to lead double lives; that is, they form two distinctly different series of compounds in which the element acts in many respects as if it were indeed two wholly different elements. Thus the element arsenic forms two oxids, first, arsenious oxid, in which two atoms of arsenic are combined with three atoms of oxygen, and, second, arsenic oxid, in which two atoms of arsenic are combined with five atoms of oxygen. Both these oxids are essentially acid in nature; that is, they readily combine with alkaline substances (bases) to form salts. For example, when arsenious oxid is treated with sodium carbonate or sodium hydroxid there is produced sodium arsenite, while arsenic oxid, similarly treated, yields sodium arsenate. The common white arsenic of commerce is merely arsenious oxid. So when in the ordinary preparation of dipping baths, white arsenic is heated with a solution of caustic soda or of carbonate of soda, the resulting liquid is essentially simply a solution of sodium arsenite.

Soon after arsenical dipping baths had come into extensive practical use it was discovered that the sodium arsenite frequently seemed to disappear slowly with continued use of the bath. Thence it was only one step to discover that the element arsenic was in fact

NOTE.—This bulletin will be of interest to cattle raisers who employ arsenical dipping baths in eradicating the Texas-fever tick.

still present in its original quantity but that it had partly changed its form and now existed to that extent as sodium arsenate,¹ a compound, as previously indicated, quite different in many of its properties from sodium arsenite. Fuller,² who independently discovered the phenomenon in the laboratories of the Bureau of Animal Industry, went further and showed that the change is essentially brought about through the growth of microorganisms in the dipping baths, other factors being relatively of little importance.

After the appearance of Fuller's paper pressure of other work prevented the obtaining of further knowledge along this line except what could be gained from the routine examination of samples from the field and an occasional desultory experiment. What was thus learned, however, indicated that the matter was probably not yet thoroughly understood and that at any rate practical studies should certainly be undertaken on the progress of the phenomenon of oxidation as it occurs in dipping vats in the field under varied conditions of actual use. The relative efficacy of solutions of arsenite and arsenate against ticks and their relative toxicity toward animals dipped therein are subjects entirely beyond the scope of this paper, but it is universally believed that sodium arsenite is a much more powerful tickicide than sodium arsenate, though at the same time more poisonous to cattle. It was clearly a matter of importance to ascertain how rapidly a change from one form to the other might go on in baths in actual use in the field, since such a change is necessarily closely related to the regularity of action of a bath upon both ticks and cattle. These field studies have been continued during the past two years.

In the meantime further published work has appeared abroad. Laws³ in explanation of certain observations suggested that, in addition to the oxidizing organisms already noted which change arsenite to arsenate, there may also exist in some baths reducing organisms which change arsenate back to arsenite. He also suggested the use of some bactericide to prevent oxidation by preventing the growth of the bacteria which cause it. Brünnich and Smith,⁴ Williams,⁵ and Holborow⁶ have made some studies of the obvious questions presented. But the published work so far seems in general hardly comprehensive enough to insure the drawing of sound practical conclusions, while in any event it is confined to certain foreign countries where dipping practice as respects strength of dip and

¹ Brünnich (Australian Association for the Advancement of Science, 1909, through *Journal of Agricultural Science*, 1911, vol. 4, p. 177) appears to have been first to make this discovery.

² Bureau of Animal Industry Circular 182, Nov. 9, 1911.

³ *Agricultural Journal of Union of South Africa*, 1913, vol. 5, p. 915.

⁴ *Queensland Agricultural Journal*, 1914, vol. 2, part I, p. 81.

⁵ *Agricultural Journal of Union of South Africa*, 1913, vol. 5, p. 68; 1914, vol. 8, p. 12.

⁶ *Rhodesia Agricultural Journal*, 1914, vol. 11, p. 579.

intervals between dipping is so different from ours as to be scarcely at all comparable.

FIELD EXPERIMENTS OF 1913.

The experiments of 1913 involved the taking at fortnightly intervals of samples from a number of vats, under as varied conditions of use as possible. That is, the vats were in different sections of the country; some were large vats at stock-yards centers, through which hundreds of cattle were passed daily; others were small vats in thinly settled localities, where only a few cattle were dipped at infrequent intervals. The samples were tested at the vat by the bureau field method,¹ were tightly sealed with wax or paraffin to prevent, by exclusion of air, oxidation en route, and were analyzed at the laboratory. Unfortunately the methods of analysis since published¹ had not then been completely worked out, for kaolin was used as a clarifying agent instead of blood-charcoal. The results, therefore, are not of the highest accuracy, but are sufficiently correct for the purpose of making the comparative studies desired. Also, the possibility of reduction by bacteria en route was not then suspected and hence no provision was made for its prevention. For the figure for actual arsenious oxid it was therefore necessary to rely in the majority of cases upon the reported result of the field test, which again is not of high accuracy.

For the purpose of making comparisons between different vats it is necessary to compare the extent to which they were used, and since vats are of very different sizes and cattle are dipped at varying intervals, it is necessary to reduce the corresponding figures to a common denominator. The "figure of use" (abbreviated "F. U."), therefore, is a figure which stands for the number of cattle dipped per 100 gallons of bath (capacity of vat) per fortnight.

The results afford the desired information most clearly and with sufficient accuracy when plotted. In the diagrams (figs. 1 and 2) the weeks during which each vat was in use are laid off horizontally, and the percentages of arsenious oxid, found by analysis, are laid off vertically. The large shaded circles where the lines begin to diverge indicate the points at which the vats were filled with entirely fresh bath; the small circles on the lines indicate the results actually obtained by analysis. The circles lying on the full lines indicate percentages of actual arsenious oxid; that is, arsenic in the form in which it was originally introduced. The circles lying on the broken lines indicate percentages of "total arsenious oxid," which includes all the arsenious oxid present, whether in its original condition or after undergoing oxidation to arsenic oxid.

¹ See Department of Agriculture Bulletin 76.

The vats were subject to all the vicissitudes of ordinary use. They sometimes lost water through evaporation and sometimes gained it through entrance of rain water. The inspectors in charge added water, chemicals, or both, whenever in their judgment the strength or volumes of the baths needed correction. Naturally, therefore,

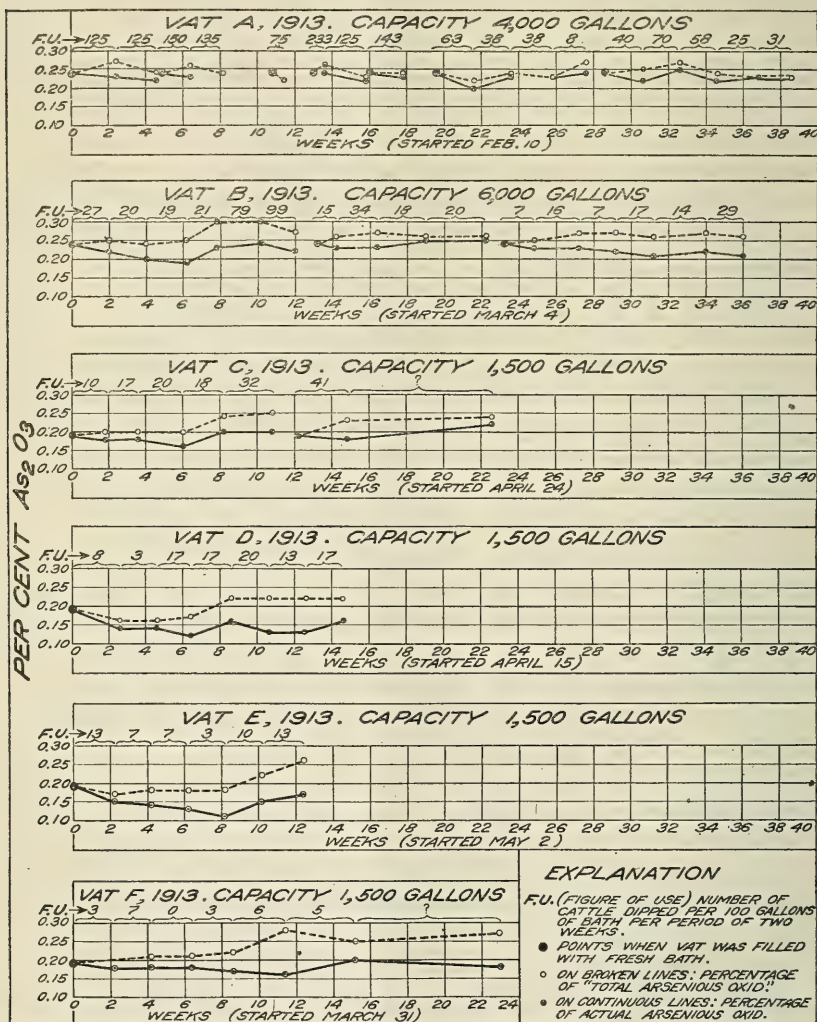


FIG. 1.—Diagram (vats A to F) showing changes in oxidation of arsenic in dipping baths.

the straight course of either the full or broken lines connecting each two consecutive circles does not mean that the composition of the dip changed gradually from point to point. The lines are introduced merely to guide the eye from one circle to the next.

The diagrams show, first, that all vats tend to become oxidized immediately or shortly after they have been put into use. This tendency may persist indefinitely, and the lines may thus spread farther and farther apart. Or, secondly, in some cases after a certain period of use, the first tendency to become oxidized may become diminished or overbalanced by a tendency in the opposite direction, so that the lines thereafter parallel or even converge. In a general way the

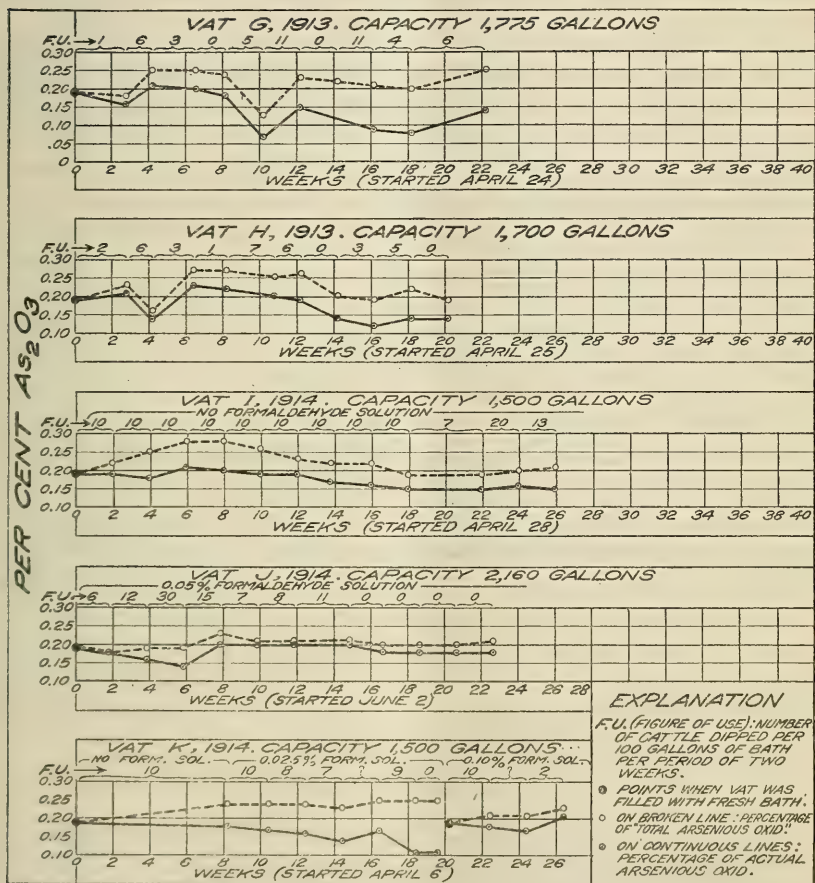


FIG. 2.—Diagram (vats G to K) showing changes in oxidation of arsenic in dipping baths.

size of the figure of use (the diagrams for 1913 are purposely arranged in the descending order of the average figures of use of the vats) evidently measures the rapidity with which the first stage, that of oxidation, progresses, and also the rapidity with which the second stage, that of reduction, first appears and the extent to which it thereafter inhibits or overcomes the original tendency to oxidation. Unfortunately, through failure of the field agents of the bureau to

send samples, many of this set of experiments were discontinued at just about the time when the second stage probably had been reached, but the phenomenon will be better illustrated in the series of experiments in 1914.

In explaining the occurrence of the second stage in the history of the vats which show it, it is not enough to say that the considerable degree of usage to which the vats were subjected and the consequent copious renewal with fresh bath allowed no time for the arsenic to become largely oxidized before it had been carried out by the cattle, for in several cases it is very plain that the lines tend to converge under a figure of use that is no greater but even decidedly less than the figure of use under which they had previously diverged, a fact explicable only by the existence in the former case of some agent which positively prevents oxidation. During the examination of samples from vat A, it happened several times that the field test made at the vat by the field agent of the bureau would be reported as showing a figure for actual arsenious oxid decidedly lower than the figure obtained through laboratory analysis, while in some such cases laboratory analysis showed no difference at all between the results for actual and total arsenious oxid; that is, the bath appeared to be entirely unoxidized. While the laboratory was puzzling over this annoying phenomenon and contemplating active steps to investigate the cause, the previously noted article by Laws came to its attention. If Laws's conjecture of the action of reducing bacteria is correct, then it was possible that in the case of these doubtful samples the analyses of the field agent and the laboratory were in fact both correct; that is, the composition of the sample had changed en route. Therefore, laboratory experiments were undertaken to determine the truth of Laws's conjecture, which was not supported by any direct experimental evidence. At the same time it seemed desirable also to run some experiments on oxidation.

LABORATORY EXPERIMENTS.

The plan of investigation was simple. Strong stock solutions of sodium arsenite and sodium arsenate were prepared by boiling the corresponding oxids of arsenic with sodium carbonate in amounts proportionate to the regular bath formula. Nutrient broth was prepared according to the formula, 5 grams solid meat extract, 10 grams Witte's peptone, and $2\frac{1}{2}$ grams sodium chlorid per liter, but sterilization appeared unnecessary for the work in view. For the tests the stock arsenic solutions were diluted, mixed with broth (about 30 per cent of the final volume), antiseptic added if desired, and the mixture inoculated with a portion of used dipping-bath from the field. No tar was added. The freshly made mixtures

were analyzed for arsenic in its two forms and were then left at room temperature for varying lengths of time, after which they were again analyzed. Some tests were carried on in open vessels (beakers) and in these the liquid was kept up to its original level or weight by daily additions of water to replace loss by evaporation.

The following detailed experiments are selected as typical from the considerable number actually performed.

Experiment 1.—To determine possible influence of high initial percentages of actual arsenious oxid upon oxidation. Total initial volumes, 250 c. c., containing 10 c. c. used bath as inoculum. Carried out in open 800 c. c. beakers, replacing loss by evaporation.

TABLE 1.—*Influence of high initial percentages of actual arsenious oxid upon oxidation.*

No. of test.	Per cent actual As_2O_3 by analysis.			
	Original.	10 days.	20 days.	30 days.
a.....	0.200	0.184	0.002	.....
b.....	.240	.234	.068	0.001
c.....	.278	.276	.138	.002
d.....	.316	.312	.146	.002
e.....	.356	.340	.176	.002
f.....	.394	.362	.232	.002

Experiment 2.—To determine possible influence of high initial percentages of total arsenious oxid upon oxidation. Total initial volumes, 250 c. c., containing identical initial amounts of actual arsenious oxid, but varying amounts of arsenic oxid. Inoculated and carried out similarly to experiment 1.

TABLE 2.—*Influence of high initial percentages of total arsenious oxid upon oxidation.*

No. of test.	Per cent total As_2O_3 .	Per cent actual As_2O_3 by analysis.			
		Original.	10 days.	20 days.	30 days.
a.....	0.204	0.084	0.194	0.013	.....
b.....	.244	.084	.226	.017	0.001
c.....	.284	.084	.261	.129	.002
d.....	.324	.084	.307	.179	.002
e.....	.364	.084	.314	.183	.002
f.....	.404	.084	.316	.189	.001

Experiment 3.—To determine the rapidity with which reduction may progress. Solution contained no actual As_2O_3 except that introduced in the used bath employed for inoculation, of which 10 per cent of final volume was added. Solution contained 0.242 per cent total arsenious oxid. A portion (test a) was placed in an entirely filled, tightly stoppered bottle, and another portion (test b) left open to the air as in experiments 1 and 2.

TABLE 3.—*Showing rapidity of reduction.*

No. of test.	Per cent actual As_2O_3 by analysis.			
	Original.	2 days.	11 days.	20 days.
a (sealed).....	0.021	0.183	.....	.....
b (open).....	.021	.183	0.142	0.002

From a consideration of the results of experiments 1, 2, and 3, we may derive the following conclusions:

1. No amount of arsenic which can reasonably be used in a dipping bath is sufficient notably to retard the rate of oxidation or of reduction, though naturally a longer time is required for the complete oxidation of a large amount of arsenic than for a small amount.

2. Under conditions favorable to reduction the action may progress with extraordinary rapidity, far overbalancing any simultaneous opposing action of oxidizing organisms. But in such cases the reducing organisms comparatively soon exhaust either their vitality or the medium and thereafter are unable successfully to oppose the slow but persistent action of the oxidizing organisms.

One must proceed very cautiously in transferring any conclusions drawn from such laboratory experiments to the far different conditions which prevail in actual dipping baths in the field. None the less, taking all available data from field and laboratory into consideration, it is believed that a fairly accurate picture may now be drawn of the conditions which prevail in dipping baths in actual use. Suppose a vat to have been thoroughly cleaned and then charged with freshly prepared bath. All the arsenic will exist in the form of sodium arsenite and, if the bath be not used for dipping, will remain in that form except for a comparatively unimportant oxidation through purely chemical agencies. But as soon as the bath is used for dipping three additions are made to it: (1) oxidizing organisms; (2) reducing organisms; (3) nutrient matter upon which one or both of the varieties of microorganisms can subsist. At first, of course, the number of organisms are few and the nutriment is scanty. Under these conditions the reducing organisms do not thrive, but the oxidizing organisms are able to grow to a certain extent, and thus are able slowly to oxidize the bath. As further dipping is done in the vat, the bath becomes richer in nutrient matter, so that the oxidizing organisms flourish correspondingly and oxidize the arsenic with increasing rapidity. But after a time, if dipping is done in sufficient amount and at short intervals, the bath becomes so rich in nutrient matter that it finally forms a favorable medium for the growth of the reducing organisms, which then begin to flourish and appreciably to counteract the action of the oxidizing organisms. We thereafter

have two fully developed opposing forces in the vat—one tending to oxidize the arsenic, the other to reduce it. Which agency will gain the ascendancy at any given time will depend chiefly on the quantity and frequency with which cattle are being put through the bath. Frequent and abundant use of a bath will favor reduction; limited and infrequent use will favor oxidation. The oxidizing organisms must be conceived as working slowly but steadily and persistently under all conditions of use; the reducing organisms may work very rapidly when they work at all, but they work only spasmodically during ordinarily brief periods when the bath happens to be sufficiently rich in nutrient matter.

The next series of experiments were upon the effectiveness of certain antiseptics against the activity of both reducing and oxidizing organisms, with the double purpose of finding (1) a reliable means for preserving samples for analysis after removal from the vat and (2) a practical means of preserving the bath in the vat.

Experiment 4.—To determine if a layer of oil floated over the surface of the bath during periods of disuse would prevent oxidation. Mixture made in the usual way, placed in beakers, and covered with layers of oil of approximate thicknesses noted below.

TABLE 4.—*Effect on oxidation of oil floated over surface of bath.*

No. of test.	Per cent actual As_2O_3 by analysis.		
	Original.	6 days.	10 days.
a (no oil).....	0.255	0.185	0.003
b (1 mm. paraffin oil).....	.255	.219	.219
c (0.1 mm. paraffin oil).....	.255	.204	.009
d (no oil).....	.194	.....	.013
e (1 mm. kerosene).....	.194	.....	.033

Experiment 5.—On the efficacy of cresylic acid as an antiseptic against oxidation. Mixtures made in the usual way, certain proportions of cresol being added in the form of liquor cresolis compositus, U. S. P.

TABLE 5.—*Effect of cresylic acid as an antiseptic against oxidation.*

No. of test.	Per cent actual As_2O_3 by analysis.		
	Original.	6 days.	10 days.
a (no cresol).....	0.201	0.027	.....
b (0.004 per cent cresol).....	.201	.106	0.006
c (0.02 per cent cresol).....	.201	.146	.003
d (0.10 per cent cresol).....	.201	.183	.180
e (0.50 per cent cresol).....	.201	.185	.181

Experiment 6.—On the efficacy of formaldehyde solution, U.S.P., as a preservative against oxidation. Carried out in open 300 c. c. Erlenmeyer flasks, earlier experiments having shown that working in open beakers led to misleading results owing to loss of formaldehyde by evaporation. Mixtures made and managed in usual way.

TABLE 6.—*Effect of formaldehyde solution as preservative against oxidation.*

No. of test.	Per cent actual As_2O_3 by analysis.		
	Original.	28 days.	71 days.
a (no formaldehyde solution).....	0.205	0.005	.....
b (0.04 per cent formaldehyde solution).....	.205	.197	0.005
c (0.06 per cent formaldehyde solution).....	.205	.197	.191
d (0.08 per cent formaldehyde solution).....	.205	.....	.193
e (0.10 per cent formaldehyde solution).....	.205	.....	.192

Experiment 7.—On the efficacy of formaldehyde solution, U.S.P., as a preservative against reduction. Mixtures made in usual way and kept in entirely filled and tightly closed bottles. The content of the mixture in total arsenious oxid was approximately 0.21 per cent, and no actual arsenious oxid was added except that introduced through the bath used to inoculate the mixture.

TABLE 7.—*Effect of formaldehyde solution as preservative against reduction.*

No. of test.	Per cent actual As_2O_3 by analysis.			
	Original.	5 days.	12 days.	18 days.
a (no formaldehyde solution).....	0.015	0.208	.....	.....
b (0.02 per cent formaldehyde solution).....	.015	.013	0.013	0.219
c (0.03 per cent formaldehyde solution).....	.015	.....	.013	.210
d (0.04 per cent formaldehyde solution).....	.015	.....	.....	.013

From these series of laboratory experiments it may be concluded:

(1) Flotation of a millimeter or so of paraffin oil upon the surface of dipping baths during periods of disuse may measurably retard oxidation. This it possibly does, not by forming a coating impermeable to the oxygen of the air, for oxygen is notably absorbed by petroleum oils,¹ but by retarding the rapidity of diffusion of oxygen into the bath underneath. Therefore oil might very possibly show to much better advantage in field experiments than in the above laboratory experiments, and doubtless deserves further study. Consideration must be given to the possibility of interference with thorough wetting of animals by a dip so treated and consequent failure to kill ticks, therefore the process should certainly not be used until

¹ Compare Comey's "Dictionary of Chemical Solubilities" and Seidell's "Solubilities of Inorganic and Organic Substances."

experiments which are not within the province of the writer have settled this point. It is of interest to note that a layer of oil will almost entirely prevent evaporation of water from the bath.

(2) Cresylic acid in admissible amounts only partially inhibits the growth of oxidizing organisms, a conclusion borne out by practical experience with proprietary dips containing that substance.

(3) Formaldehyde solution is a powerful and effective antiseptic against both classes of organisms, and inasmuch as it does not interfere with analytical methods for the determination of arsenic, it is appropriate as a preservative of samples of bath taken from a vat for chemical analysis, as recommended elsewhere by the writer.¹

Similar experiments were tried on some other antiseptics, especially those which would not interfere with analytical estimations of arsenic. Nothing was found, however, which at all approached formaldehyde in effectiveness and general applicability.

FIELD EXPERIMENTS OF 1914.

The experiments of 1914 were directed toward determining the efficacy and practical applicability of formaldehyde as a preservative against oxidation of dipping baths in the vat. Three vats were selected which were expected to be closely comparable in degree of usage, etc. One of the vats received no addition of formaldehyde and thus served as a check. The samples taken from the vats were further treated with formaldehyde and shipped in sealed bottles, while methods of analysis ¹ had by this time been thoroughly worked out. The analytical results of this series of experiments were very accurate, but are nevertheless best presented in the form of diagrams as in the case of the dipping experiments of 1913, no further explanation of the diagrams accordingly being necessary.

The diagram for vat I is very characteristic. Vat K, up to the twentieth week, shows what had been expected (from unpublished data) might occur if too little formaldehyde were used, namely, that the reducing organisms are more sensitive to it than are the oxidizing organisms, so that too little formaldehyde is worse than none at all. Vat J, as well as vat K after the twentieth week, shows that a sufficient amount of formaldehyde does decidedly decrease the extent to which oxidation progresses, especially after the vat has been in use for a few weeks, but for the first four to six weeks formaldehyde seems to be practically without effect in modifying the rate of oxidation. This is precisely the period during which the fresh antiseptic should be most effective against the thinly sown and scantily nourished organisms. It can only be concluded that in recently prepared baths the notable oxidation which may occur is in fact not chiefly the result of bacterial growth but of purely chemical processes. In

¹ Department of Agriculture Bulletin 76.

his first paper Brünnich¹ found that blowing air through solutions of sodium arsenite produced appreciable oxidation if pine tar or certain other substances were present, and Cooper and Freak² confirmed Brünnich's observations. From the present experiments the power of tar to promote oxidation seems to be exhausted in a few weeks, and thereafter the progress of oxidation, in accordance with the conclusions of Fuller, must be attributed to the growth of microorganisms.

GENERAL CONCLUSIONS.

The main conclusions already discussed in detail under the several series of experiments may be briefly summarized as follows:

(1) All used arsenical dipping baths may be expected to contain (a) oxidizing organisms which work slowly, but steadily and persistently, and (b) reducing organisms which work very rapidly at times, but spasmodically. The reducing organisms exert an appreciable effect only in vats which are used at frequent intervals for dipping large numbers of cattle. The ordinary vat, used once a fortnight, is likely to show only a slow, steadily progressing oxidation of the arsenic, and periodical analyses or tests³ must be made if proper dipping strength is to be maintained.

(2) Formaldehyde solution (37 per cent), used in the proportion of 1 gallon to every 1,500 gallons (8½ fluid ounces to 100 gallons) of liquid introduced into the vat, appears a safe and effective means for reducing oxidation to a low figure. But since there seems to be no evidence that under ordinary conditions oxidation is ever likely to progress so far as to result in the use of baths injurious to cattle, the question of the use of formaldehyde is purely economic. The writer believes that in most cases it will be cheaper to let some of the arsenic go to waste through oxidation. When the cost of a gallon of formaldehyde about equals the cost of all the materials necessary to make 500 gallons of dipping bath, there will probably be little financial gain either way, while there may be some real profit in its use through saving of labor in preparing dip and through the reduction of offensive odor from the bath by keeping it under antiseptic conditions.

¹ Australian Association for the Advancement of Science, 1909, vol. 12, p. 129.

² Journal of Agricultural Science, 1911, vol. 4, p. 177.

³ Department of Agriculture Bulletin 76.

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Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief



Washington, D. C.



November 23, 1915

THE DOG AS A CARRIER OF PARASITES AND DISEASE.

By MAURICE C. HALL, Ph. D.,
Assistant Zoologist, Zoological Division.

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In the evolution of civilization the dog was one of the most useful animals ever domesticated by man. In addition to his usefulness, other admirable qualities have endowed him with a certain sentimental esteem as a pet. The part the dog plays as a carrier of disease, however, has only recently been recognized, and his status has not yet been changed to satisfy modern hygienic precautions or even to meet altered conditions of life in cities.

Whether in the city or in the country, the dog is commonly allowed a degree of freedom which is approached only by that of the less social and consequently less dangerous cat. Liberties which we do not allow our horses, cattle, children, or selves are extended by many persons to their dogs. They are permitted to run unquestioned over lawns or farms, to plant bones in flower beds, to litter up porches and walks with trash and filth, to lick the faces of children, to wipe their muddy paws on strangers' clothing, to go unmuzzled when rabies with its terrible agony and attendant death is abroad, and to roam afield at nights and run sheep to death.

NOTE. This bulletin points out the increasing damage done by the stray and uncured-for dog as a carrier of parasites and disease germs harmful to both man and live stock, and is especially intended for the use of physicians, veterinarians, and health officers.

As has been said, the dog himself has many delightful and useful qualities. It is our thoughtless tolerance of his present unwarranted liberty and license that permits this survivor of the days when the dog was man's faithful and valuable ally against the rest of the animal world to become a pest and a danger. There is a growing conviction that while his innate qualities and the fund of affectionate sentiment which attaches to him warrant the preservation of the dog with a responsible owner who will keep him clean and free from vermin of all sorts, hold him within reasonable bounds and restraint, and assume responsibility for his acts, on the other hand, the ownerless dog, the dog which carries vermin and disease, the dog which kills sheep or destroys property of any sort, the trespasser—these dogs must be eliminated.

The case against the unrestricted dog is based on two counts—that he is a nuisance and that he is dangerous.

That most dogs are allowed too many liberties and too much familiarity with people is a matter of common knowledge. Transgressions on the part of dogs range from simple trespass to the habit of biting without provocation and to the wanton killing of sheep.¹

The direct monetary damage done by unrestricted dogs, while great, is even less important than the indirect harm they work as carriers of disease. It is the purpose of this paper to show how improperly-cared-for dogs act as agents in the spread of diseases, particularly parasitic diseases, affecting man and live stock.

DISEASES AND PARASITES CARRIED BY THE DOG.

Dogs probably play a part in the spread of diseases due to fungi, such as ringworm and favus, and are sometimes important carriers of bacterial and filterable-virus infections. In the recent outbreak of foot-and-mouth disease, it was determined beyond any reasonable doubt that dogs were responsible in some instances for the spread of the disease, not only from one farm to another, but from one State to another. The dog is of primary importance and in many instances the sole carrier in the case of many dangerous and even deadly animal parasites of man and the domestic animals, and is especially notorious as the carrier of rabies. Some of these parasites depend so absolutely on dogs as carriers during certain stages of their life history that they would probably or certainly become extinct if dogs were not available as hosts. The long list of important diseases and parasites which are conveyed by the dog to man and the domestic animals and which are present in this country is as follows: Rabies in man and stock; hydatid in man and stock; gid in stock (and possibly in man also);

¹ See Farmers' Bulletin 652, "The Sheep-Killing Dog."

muscular cysticercosis, or so-called "measles," in sheep; muscular cysticercosis, or "measles," in reindeer; cysticercosis of the liver and mesenteries in stock; tapeworm in man, especially in children; roundworm in man; tongueworm in man and stock; and fleas and ticks which transfer from the dog to man and which may in this way transmit disease and parasites. The above list is sufficient to show that the dog is of major importance as a carrier of parasites dangerous to man and domestic animals. An elaboration of the list follows.

RABIES.

It has been known for over 2,000 years that what are called mad dogs, those affected with the disease termed rabies, hydrophobia, or lyssa, could transmit this disease to stock and to man by biting them. For 2,000 years the disease has been reported in sporadic and epidemic outbreaks. It is now recognized as a widespread, acute, infectious disease of the central nervous system, characterized by extreme nervous excitability. It is a disease which, if untreated, leads to a certain death of the most horrible and agonizing sort. It owes its wide distribution and its very existence almost exclusively to the dog. The disease may manifest itself in dogs or other animals under the form of dumb rabies or furious rabies. In dogs there is commonly evidence of depraved appetite, the dog eating sticks, leather, and stones, and the finding of such things in the stomach is a suspicious indication of possible rabies. There is a partial or complete paralysis of the throat, and the resultant difficulty in drinking is the basis of the erroneous idea that the mad dog is afraid of water. As a matter of fact, such dogs are often very eager for water but are unable to swallow it. The disease seems to have some specific effect on the centers controlling biting, the feature on which transmission of the disease depends, and not only dogs but such animals as the horse show a tendency to bite when affected with rabies. The disease is suspected of being due to a parasitic protozoan, though as yet too little is known regarding this to warrant a definite statement. An examination of the brain of rabid animals shows certain cell inclusions known as Negri bodies (fig. 1), the nature of which is not at present well known.

It has been pointed out in a previous publication¹ of the United States Bureau of Animal Industry that rabies is becoming increasingly prevalent in the United States. That publication cites the fact that the New York Pasteur Institute had treated 1,608 cases of hydrophobia during the first 11 years of its existence, up to 1901. The Chicago Pasteur Institute, established at about the same time as

¹ Rabies and its increasing prevalence. By George H. Hart. Bureau of Animal Industry Circular 129. Washington, 1908.

the New York Institute, had treated 3,010 persons for hydrophobia during the first 17 years of its existence, up to 1907. The Baltimore Pasteur Institute had treated over 1,000 cases up to 1908. Many more such figures could be cited for the numerous other Pasteur

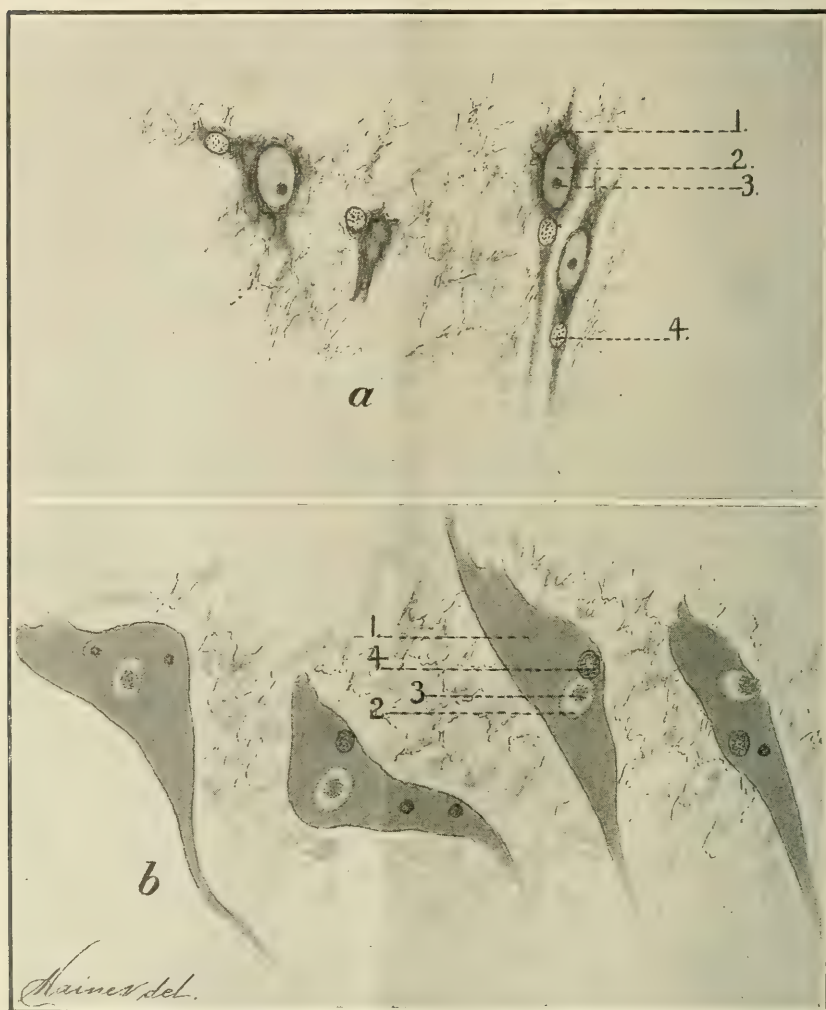


FIG. 1.—*a, b*, Nerve cells of the brain, showing Negri bodies, a diagnostic factor in rabies. 1, cytoplasm of cell; 2, nucleus of cell; 3, nucleolus of cell; 4, Negri body in cytoplasm of cell. (After Hart.)

institutes in this country. In 1908, 111 deaths of persons from rabies were reported in the United States, and owing to our inadequate statistical methods we have nothing like exact data in regard to the extent and distribution of the disease or the number of cases

and deaths. In 1911, according to Stimson,¹ there were 94 fatal cases in man, a decrease from the figures for 1908, which is probably due largely to the fact that in 1911 there were 4,625 persons treated for rabies in this country. Mohler² states that there are only three States in the Union—Idaho, Utah, and Nevada—from which it has been impossible to obtain positive information to the effect that cases of rabies have been found in them. The disease has since been reported from Idaho and Nevada.

Rabies is an easily preventable disease. In the present state of our knowledge as to its mode of transmission, there is no reason for its continued existence. It may be prevented and in time eradicated by simply muzzling dogs for a sufficient period to allow the disease to die out. Such a minor restraint on the dog as muzzling was sufficient to eradicate rabies from England. The first case since 1902 has just been reported in the spring of 1915, and this case occurred in a dog that was being held in the six months' quarantine which is enforced on all dogs brought into that country to prevent the disease being reintroduced. Australia and New Zealand have never had any cases of rabies, and a system of quarantine and inspection is provided to prevent its introduction. It has been practically or completely eradicated from Sweden, Norway, and Denmark by rigid enforcement of muzzling ordinances.

HYDATID.

Hydatid disease occurs in man, cattle, sheep, horses, hogs, and numerous other animals. It is caused by the presence of the so-called hydatid (technically known as *Echinococcus polymorphus*, *Echinococcus granulosus*, *Echinococcus multilocularis*, etc.) in such tissues as the liver, kidney, muscles, brain, lungs, etc. The hydatid is a bladder worm or larval tapeworm (fig. 2), and is characterized by its thick laminated cyst wall. The original bladder frequently develops daughter bladders on the inside or on the outside, and in these or the original bladder there develop brood capsules containing tapeworm heads. There are probably two species of hydatid, though they are commonly considered a single species. The bladder worms are often as large as an orange and may be as large as a child's head. Growth and the formation of daughter bladders may go on for an indefinite period. There have been cases in which hydatids have existed in man as long as 30 years before the death of the patient finally ensued. Their presence in the body causes various forms of

¹ Rabies in the United States during the year 1911. By A. M. Stimson. Public Health Reports, vol. 27 (28), July 12, 1912, pp. 1098-1101.

² Rabies or hydrophobia. By John R. Mohler. Farmers' Bulletin 449. Washington, 1911.

hydatid disease, depending on the location of the parasite. The effects are very serious and the prognosis is always grave. A conservative estimate gives a death rate of 13.6 per cent of the persons infected (Vegas and Cranwell). The growth of the bladder gives rise to various troubles as a result of pressure, obstruction, perforation of important organs, necrosis of tissue, liberation of poisonous products, secondary bacterial infections, rupture of the hydatid, and secondary hydatid infestation following rupture of the cyst. It is commonly necessary to resort to surgical interference for the removal of the hydatid. Operation is often very difficult and may have to be repeated, owing to the presence of small external daughter bladders which are easily overlooked or incapable of detection. A

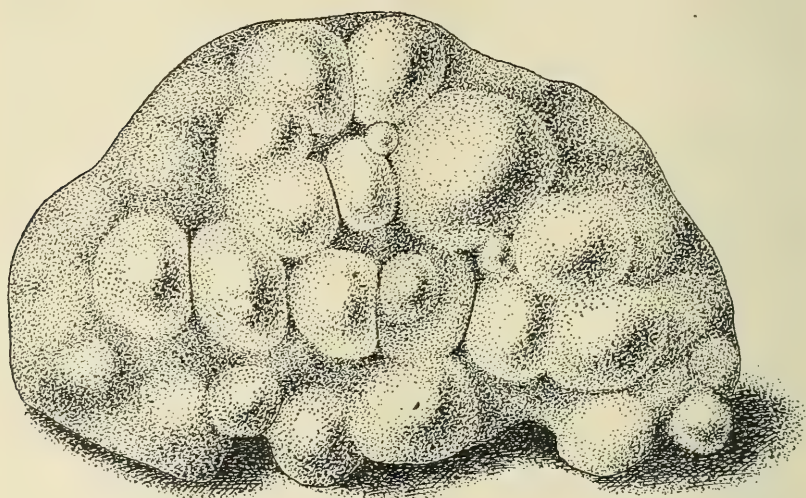


FIG. 2.—Portion of a hog's liver infested with hydatid bladderworm (*Echinococcus granulosus*). Natural size (after Stiles).

case has been recently recorded where the patient had to be operated on four times before the recurrence due to daughter bladders had ceased.

In the lower animals hydatids are probably less often a cause of death, owing to the slow growth of the parasite and the fact that the affected animals are likely to be slaughtered before sufficient time has elapsed for the parasite to become a menace to the life of the animal.

If brood capsules containing the tapeworm heads are eaten by dogs—a thing which is apt to occur on farms where the viscera of slaughtered animals, especially when they appear unwholesome, as they would in hydatid disease, are thrown out on the fields or fed to

dogs—these tapeworm heads pass uninjured to the intestine of the dog and give rise to numerous very small segmented tapeworms, *Tænia echinococcus* (fig. 3). The dog is practically the only carrier of this tapeworm. The tapeworm attains a length of only about half a centimeter (three-sixteenths of an inch) and consists of a head and three segments. The sexual organs develop in the second segment and eggs are present in the third segment. These eggs pass out in the feces of the dog and infect pasture, soil, and water. They are spread broadcast on grass, in drinking water, on products intended for human food, on children's toys, and on all sorts of objects in places frequented by the dog. The rooting habit of the hog predisposes it to hydatid disease, as it is extremely likely to swallow some of these eggs in feeding if there is a dog with the hydatid tapeworm anywhere around. But even the most careful persons have no assurance of safety where there are such dogs. Eggs from the feces of these dogs may wash considerable distances and ultimately land on lettuce, radishes, or other vegetables. They may get on the hand from contaminated tools or farm implements, or from the dog's skin. Persons who allow dogs to lick their hands or faces run the risk of acquiring and ingesting the eggs of this tapeworm. When such eggs, which are, of course, too small to be seen with the naked eye, are ingested by man or animals, the shell digests off and releases a small embryo armed with six hooks. By means of these hooks the embryo bores its way through the wall of the stomach or intestine and into the blood current. Here it is swept around till it lodges. At the point of lodgment the embryo starts to develop into the hydatid or bladder worm already noted. The parasite must always be transmitted from the dog to other animals by the ingestion of the egg from the tapeworm in the dog, and from other animals back to the dog by the dog eating diseased carcasses or parts of carcasses. It can not be transmitted in the form of the hydatid from an infected animal to another animal nor in the form of the tapeworm from one dog to another.

Prevention depends in part on a proper handling of slaughtered animals and of those dying from any cause. An obvious aid in preventing this disease would be to destroy diseased portions of animals slaughtered for food or for any reason. This is best accomplished at



FIG. 3.—*Echinococcus granulosus* (*Tænia echinococcus*), the hydatid tapeworm from the intestine of a dog. Enlarged (after Leuckart).

our large packing houses where such diseased portions are tanked at temperatures which insure the destruction of all parasites of any sort. On the farm it may be accomplished by boiling any viscera before feeding them to dogs or other animals. The viscera should never be thrown out on the fields. The practice is objectionable of itself; it furnishes a breeding place for flies and is in every respect insanitary and improper. Viscera and carcasses, if not cooked and fed, should be burned, buried with lime, or disposed of in such a manner that they can not be devoured by dogs.

An additional method of preventing hydatid disease, and the one that should be emphasized here, is for the owners of dogs to keep them up, and to have stray dogs disposed of by the proper authorities. A person should have substantially the same supervision of his dog's food, for his own sake and for the sake of the dog, that he has of his children's food. It is dangerous as well as unwholesome to allow dogs to forage for a living. A man who does not properly feed his dogs has a poor claim to their care and ownership. Dogs should be kept out of human habitations and treated in general with more regard to their possibilities as disease carriers.

Hydatid disease is fairly common in Europe. It is quite common in Iceland, India, Eastern Siberia, Algeria, Tunis, Australia, and some South American countries. It has been permitted to assume the proportions of a serious menace in Australia, and 3,000 cases of hydatid disease in human beings were reported from there between the years 1861 and 1882. In at least two South American countries hydatids are so common that the sanitary authorities have issued illustrated placards warning against the disease.

Over 240 cases of hydatid in man have been recorded from the United States up to 1902. Over most of the United States hydatids are comparatively infrequent in domestic animals, but they are not so rare that they are curiosities to meat inspectors. Numerous condemnations of organs and parts of carcasses are reported every year from the various meat-packing establishments under Federal inspection. Some recent abattoir figures show an alarming prevalence of this disease in domestic animals in some parts of this country, notably in certain localities in Virginia, Arkansas, and Oklahoma; and the prevalence of hydatids in domestic animals is an index of the danger to which people are exposed. It is, moreover, desirable that we apply preventive measures before a larger list of cases in man makes both curative and preventive measures imperative. The bare fact that hydatids occur at all in the United States is of itself a cogent argument for the suppression of the dog nuisance as a measure necessary for the public welfare.

GID.

Gid disease, like hydatid disease, is due to the presence of a bladder worm, or larval tapeworm, in the tissues. The bladder worm (known as *Multiceps multiceps* or *Cœnurus cerebralis*) (fig. 4) which causes gid resembles the hydatid bladder worm in that one bladder worm may produce large numbers of tapeworm heads, and the tapeworms resulting from these heads occur in the intestines of dogs, as in the case of the hydatid tapeworm. The bladder worm causing gid differs from the hydatid in that it has a thin, delicate, membranous wall instead of a thick laminated wall; it does not produce daughter cysts as the hydatid does, and it occurs only in the brain and spinal cord instead of in any tissue. The adult tapeworm in the dog, commonly known as *Tænia cœnurus* (fig. 5) attains a length of 2 or 3 feet instead of a small fraction of an inch.

Gid is principally a disease of sheep, though it is fairly common in cattle and there are some cases from the horse and the goat. In 1910¹

the writer stated that there were no valid cases of the disease in man. Since then Brumpt² has published one case which apparently must be accepted as a good case.

The life history of the gid parasite is practically the same as that of the hydatid. The gid bladder worm is called a cœnurus. When this cœnurus is eaten by a dog, the tapeworm heads on the cœnurus pass to the intestine of the dog and give rise to a tapeworm which

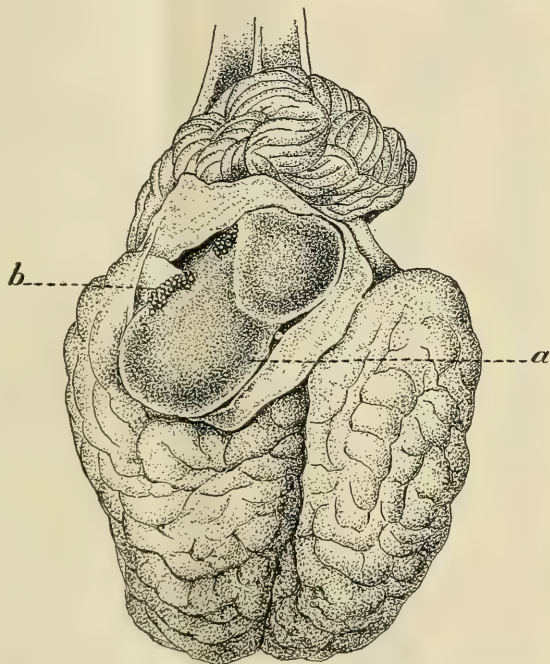


FIG. 4.—Brain of giddy sheep, showing gid parasite, *a*, Gid parasite or bladder worm; *b*, heads on bladder worm. (After Numan, 1850, Pl. I, fig. 1.)

¹ The gid parasite and allied species of the cestode genus *Multiceps*. I. Historical review. By Maurice C. Hall. Bureau of Animal Industry Bulletin 125, pt. 1.

² Précis de parasitologie, 2d ed., pp. 281–283. 1913.

may attain a length of 2 or 3 feet. In the terminal segments are eggs, and these segments with the contained eggs pass out in the feces of the dog and contaminate vegetation, soil, and water. Such herbivorous animals as sheep, which graze over range or pasture contaminated in this way, pick up these eggs as they feed and swallow them. In the stomach of the sheep the shell is digested and the small, hooked embryo released. The embryo bores its way through the wall of the digestive tract and into the blood vessels

and is carried around until it lodges somewhere. Embryos which do not lodge in the central nervous system start to grow, but very soon perish. Very commonly, however, the parasite makes its way to the central nervous system, lodging as a rule in the brain, though it occasionally occurs in the spinal cord. In the brain the embryo grows to form the bladder worm or *cœnurus*, and this may attain the size of an egg, or even a larger size. As it grows it presses upon the adjacent portion of the brain and destroys it. The pressure and the irritation, due to the hooks with which the tapeworm heads of the *cœnurus* are provided, cause very distinctive symptoms, the sheep commonly holding its head in an odd position and walking in a circle toward one side or the other. Unless the *cœnurus* is removed by operation the sheep invariably dies. When the brain of such a sheep is eaten by dogs—and dogs very readily eat the brains of sheep by licking them out through the large opening



FIG. 5.—Adult gid tapeworm from the dog. Natural size. (Specimen No. 4031, Bureau of Animal Industry helminthological collection.)

at the base of the skull—the *cœnurus* is ingested with the brains and the tapeworm heads pass to the intestines of the dog and give rise to the adult tapeworms. As in the case of the hydatid, the gid parasite must always be transmitted from the dog to other animals which eat the eggs from the dog tapeworm, and from the other animals to the dog by the dog eating the brain or at least the *cœnurus* from the brain of a giddy animal.

One preventive measure for suppressing gid is, of course, to destroy the brains and the cœnuri of giddy animals, which can be done by burning them or by breaking the skull and covering the brain with formaldehyde, sheep dip, or some similar substance. Another measure is to administer a vermifuge to sheep dogs and so rid them of their tapeworms, and to do this often enough to keep them free from tapeworms. But it is obviously of little avail to a sheepman to have his own dogs free of tapeworm if his neighbor's dogs or ownerless dogs or strays of any sort are free to carry tapeworm onto his range or pasture and infect the grazing and thereby infect his sheep. From losses originating in this way he must be protected by measures looking to the restraint of dogs that recognize an owner and the elimination of those that do not.

Gid has been reported from several States in this country, but it is most prevalent in Montana, especially in the northern half of that State, where gid has had a foothold for a quarter of a century and where the losses for some years total about \$10,000. There is evidence of the occurrence of gid in Arizona, and outbreaks have occurred in recent years in New York, Iowa, and Kansas. There have been reports, apparently correct, of its occurrence in Ohio, Illinois, Michigan, Missouri, Oklahoma, and Nevada. It is a constant source of loss in many European countries, and at various times has proved a veritable scourge to the sheep industry of these countries.

CYSTICERCUS (MEASLES) IN SHEEP AND OTHER ANIMALS.

Muscular cysticercosis ("measles") in sheep.—The presence of small bladder worms in mutton has recently been shown by Ransom¹ to be much more common than had been suspected, and to be due to a tapeworm in the dog and not to a tapeworm of man as had been supposed. His investigations showed that under careful inspection the percentage of affected sheep in this country has amounted to 2 per cent or more, and that approximately 20,000 sheep carcasses were retained in 1912 in abattoirs under Federal inspection on account of "sheep measles" due to this parasite.

The bladder worm, *Cysticercus ovis* (fig. 6), in the meat of sheep is oval and ranges in size from about one-third of a centimeter (one-eighth of an inch) to almost a centimeter (three-eighths of an inch) in length. Inside of this bladder there is a single tapeworm head, in which respect, as well as in size, this cysticercus, as it is called,

¹ *Cysticercus ovis*, the cause of tapeworm cysts in mutton. By B. H. Ransom. Journal of Agricultural Research, U. S. Department of Agriculture, vol. 1, pp. 15-58. 1913.

differs from a hydatid or a cœnurus. Numerous cysts, however, may be scattered through the musculature, so that in their numbers there is a compensation, so to speak, for their small size and lack of a multiplicity of heads. Inasmuch as the presence of these cysts calls for condemnation of a part or all of the infested carcass, according to the degree of infestation, and the number of carcasses amounts to 20,000 a year, this parasite has considerable economic interest for

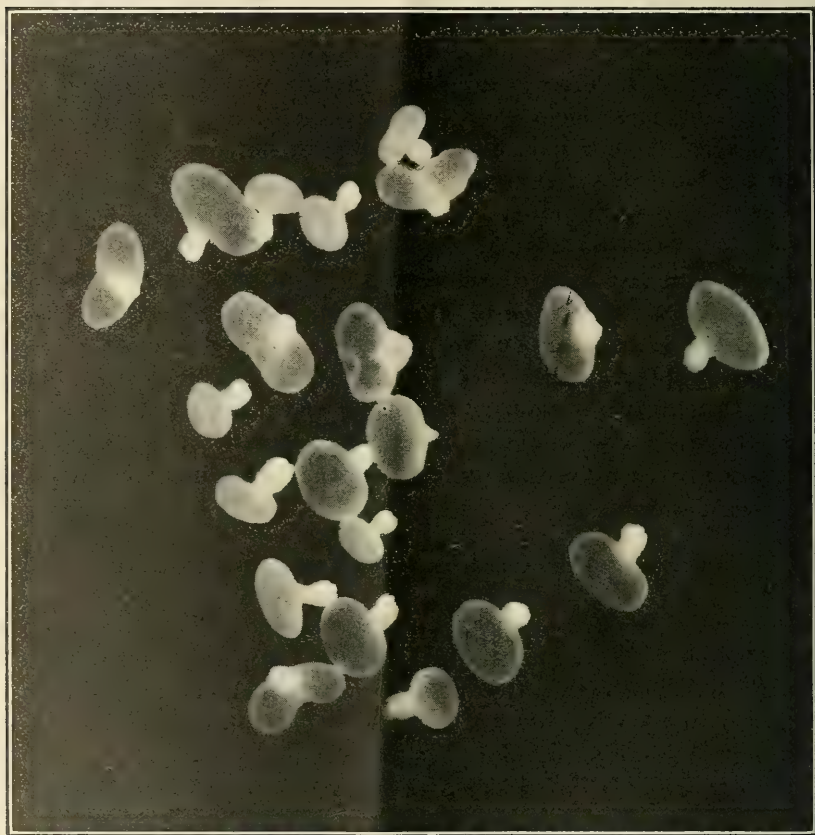


FIG. 6.—Bladder worm (*Cysticercus ovis*), a tapeworm cyst infesting the meat of sheep.
(From Ransom.)

this country, and never more than at the present time when the "high cost of living" is such a vital topic.

When one of these cysticerci from mutton is ingested by a dog, the tapeworm head passes undigested to the dog's intestine and develops into a fairly large tapeworm, comparable to the gid tapeworm. Similarly, this tapeworm, *Tenia ovis* (fig. 7), produces eggs which are passed out in the feces of the dog, and which are ingested

by sheep as they graze over range or pasture or drink water contaminated by these feces. In the sheep the eggshell is digested, the released embryo bores through the tissues and comes to rest usually in the edible musculature, and the bladder worm develops to the cysticercus capable of again infecting the dog. In cases of heavy infestation sheep are liable to die in the course of two to three weeks, but as a rule the health is not perceptibly affected. Here, as in all similar cases, the parasite must pass from the dog to the sheep and from the sheep to the dog.

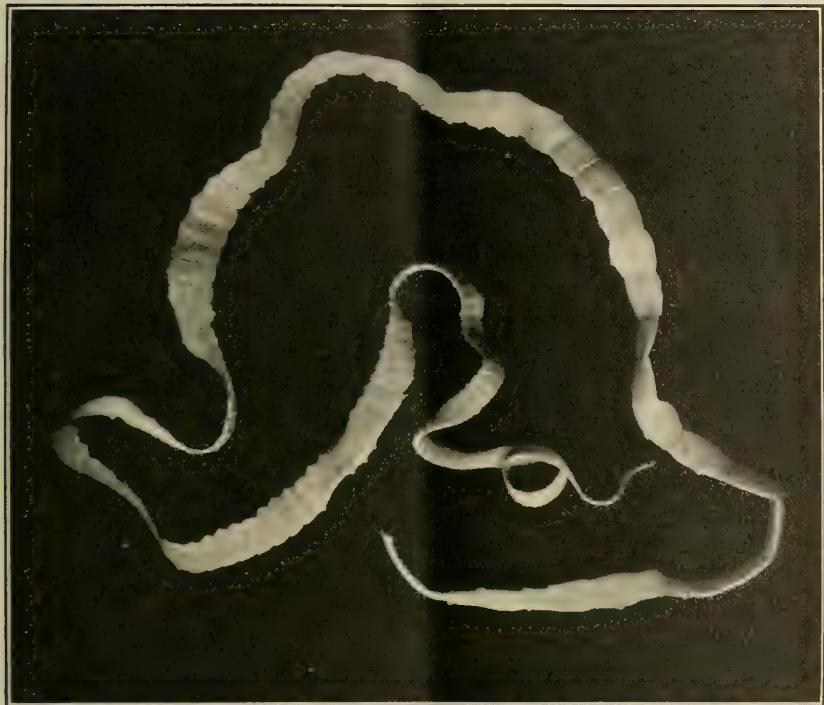


FIG. 7.—Tapeworm (*Tania ovis*) developed by feeding bladder worm (*Cysticercus ovis*) to a dog. (From Ransom.)

The parasite has been found in Europe, Africa, and New Zealand. It has been found thus far in seven States in this country. It appears to be particularly prevalent in the West, a fact that is possibly related to carelessness on the part of the western sheepmen as regards the disposal of carcasses of sheep dying on the range. Such sheep are usually left lying where they die, a practice which aids in the spread and continuance of gid, and which serves the same purpose in the case of the "sheep measles" parasite that throwing diseased viscera of hogs onto the fields does in the case of the hydatid parasite. The sheep dog is probably the principal carrier of the parasite,

so that neglect on the part of sheep owners is a leading reason for its prevalence.

The prophylactic measures against "sheep measles" are essentially the same as those against gid and hydatid. Diseased portions of slaughtered sheep and dead sheep which have not been slaughtered should be cooked before being fed to dogs or else disposed of so that dogs can not eat them. Ownerless dogs should be destroyed and other dogs properly fed and kept free from tapeworm.

Muscular cysticercosis ("measles") in reindeer.—This parasite deserves special mention in view of the possibility that the Alaskan reindeer may become important in connection with the meat supply of this country. A large percentage of these animals, which are rapidly increasing in numbers, are infested with a measles parasite apparently the same as the form known to be the intermediate stage of a dog tapeworm (*Tania krabbei*). This is not only serious so far as concerns the reindeer industry, but the possibility that the parasite may become established in other food animals is not altogether excluded, though probably remote. *Tania krabbei* occurs in Europe and Asia and was likely introduced with the reindeer or dogs imported into Alaska, though the Alaskan form may be a native parasite already present in American reindeer and carnivores before the importation of the Old World animals.

Cysticercosis of livers and mesenteries.—Cysticercosis, or the presence of cysticerci, or bladder worms, in the livers, mesenteries, and omentum or "fat caul," is very common in cattle, sheep, and hogs throughout the United States. These bladder worms, *Cysticercus tenuicollis* (fig. 8), are usually 1 or 2 inches in diameter, and the cyst contains a single tapeworm head. The life history follows the same general plan that has been outlined for the preceding tapeworms. When such bladder worms, or viscera containing them, are eaten by dogs, the head contained in each cyst passes to the intestine and develops a tapeworm (*Tania hydatigena* or *Tania marginata*) (fig. 9) in the dog; the eggs produced by the tapeworm pass in the feces of the dog onto the vegetation or into the drinking water of cattle, sheep, and hogs; the eggs ingested by these animals in feeding or drinking release an embryo which makes its way, via the portal system, from the digestive tract to the liver; in the liver the embryo develops into a small bladder worm (*Cysticercus tenuicollis*) which after some time slips from the liver into the body cavity and lodges in the omentum or mesenteries, where it attains its final growth; the bladder worm may then be eaten by a dog, on the death of the host

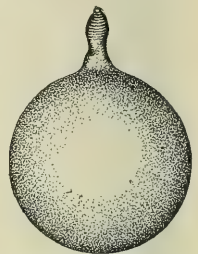


FIG. 8.—*Cysticercus tenuicollis*, the thin-necked bladder worm from the body cavity of cattle, sheep, swine, etc. Natural size (after Stiles).

animal in which the bladder worm occurred, and will give rise to a large tapeworm, which may attain a length of 5 meters, or about 16 feet.

Extensive burrowing of the parasites in the substance of the liver during the early period of the bladder-worm development may cause serious damage, and in cases of heavy infestation may result in the death of the animal. Bacterial infection may complicate the parasitic invasion. In the United States, flocks of sheep in which this parasite is not present are rare, and a high percentage of livers, especially lamb livers, are condemned in abattoirs under Government inspection because of infestation with this parasite.

Prevention calls for a proper disposal of the viscera of slaughtered animals with a view to keeping the viscera, unless first properly cooked, away from dogs. It also calls for a routine tapeworm treatment for dogs, an adequate knowledge and supervision of the food and feeding habits of dogs, and the elimination of the dog without a responsible owner.

TAPEWORMS, ROUNDWORMS, ETC.

Double-pored tapeworm.—Of the numerous species of tapeworm occurring in the dog, many of them not mentioned in this paper because they do not have a larval stage or bladder worm in man or stock, one species may occur in man in the form of the adult tapeworm. This species, commonly known as the double-pored tapeworm (*Dipylidium caninum*), has a life history which follows the same general plan of alternation, from a tapeworm in the dog to a larval tapeworm in an intermediate host and back to the dog, that the tapeworms already mentioned follow. It is, however, peculiar in that the intermediate stage,

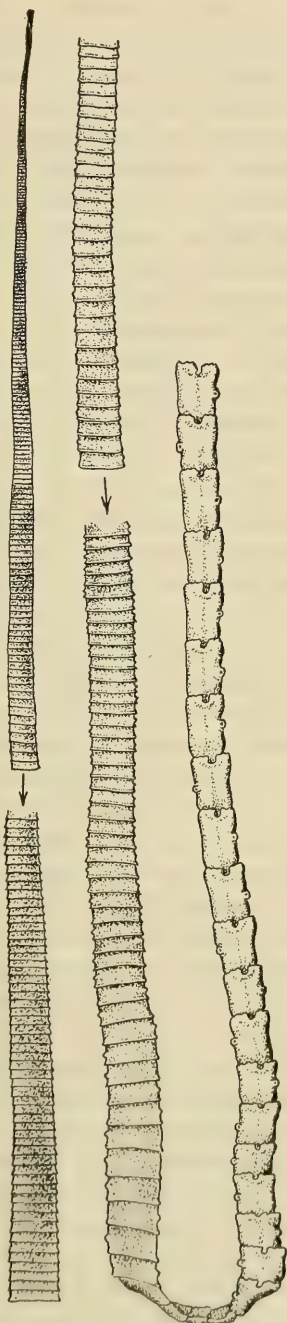


FIG. 9.—*Tænia hydatigena*, the adult tapeworm from the intestine of the dog. Natural size (after Stiles).

or larval tapeworm, is very small and develops in the dog flea or louse instead of such an animal as the sheep. The flea or louse ingests the eggs of the tapeworm by biting the skin of the dog where it is contaminated by the feces of the animal or by soil containing eggs from the feces, or possibly by biting the tapeworm segments containing the eggs as these segments pass from the dog. Within the flea or louse the egg develops into a larval tapeworm, necessarily a very small larva, known as a cryptocystis. Owing to the pain and irritation resulting from the bites of these fleas and lice, the dog will from time to time root out the offenders and inadvertently or intentionally, as the case may be, swallow them. In the stomach of the dog the fleas and lice are digested and the little tapeworm larva set free to pass on to the intestine and develop into a tapeworm, which may attain a length of 35 centimeters, or about 14 inches.

When flea-infested or lousy dogs are allowed unwarranted privileges in the house, permitted to put their paws on the table during meals, to eat from the same dinner plates and saucers, to lick the baby's face and the children's candy, to sleep at the foot of a person's bed or on a pillow near a person's head, the chance of a flea landing unperceived in food that will hold and conceal the flea, the chance of its getting to the baby's mouth or adhering to the sticky candy which the child eats with no regard to incidental contamination, is very good. Under such conditions the ingestion of fleas or lice infested with the larval tapeworm in question is likely to occur, and the result is the development of the adult tapeworm in the person ingesting them. This tapeworm has been found in children more frequently than in grown persons, in one case in a baby only two months old, but it has been found in an adult 38 years old. As many as 238 worms have been found in a single person. Up to date, 76 cases of this tapeworm in man, usually in children, have been reported, and a number of these are from the United States.

The remedy here concerns the family dog rather than the stray. The dog should be treated like a dog, not like a person. The dog is an animal with its habits fixed by all the facts that arise from the one fact that it is a dog. The fact that a dog is not a person, that it is different from people, is important. The lack of hands compels the dog to use his tongue for a wash rag, but we are under no such necessity, and there is nothing in the situation that calls for our permitting our own or our neighbor's dog to use the same tongue subsequently on our hands or face. It is an absurdity to ask that the cook and the table service be clean and then allow a dog to put his feet on the table, to sniff at the food, to lick the hand or face, and to

do the dozens of other dangerous and improper things that some dogs are allowed to do.

The presence of one or a few of these tapeworms in man probably occasions very little inconvenience as a rule. At the same time the tapeworm has an unpleasant habit of burrowing through the intestinal mucosa, thereby destroying its integrity and exposing it to the attack of any pathogenic germs that may be present in the intestine. The same burrowing habit makes it difficult to remove successfully the entire worm with the head, and a failure to remove the head, owing to its being buried in the mucous lining of the intestine, results in the subsequent development of new tapeworm segments from the head and a renewal of infection. At its best, a tapeworm is a thing unpleasant to contemplate as an inhabitant of our intestines. The presence of the tapeworm under discussion here is, moreover, evidence of careless or unclean habits on the part of the person infested.

Prevention requires that the unwarranted liberties and freedom of the dog be curtailed; that he be kept free not only from tapeworm but from such external parasites as fleas and lice. The accomplishment of the latter measure calls for keeping a dog clean and restraining him so that he will not be allowed to run at large with vagrant flea-infested and lousy dogs.

Roundworm.—Among the other parasites of the dog there is a nematode or roundworm, scientifically known as *Toxascaris limbata*, which, like the tapeworm just mentioned, may occur in man in the same form in which it occurs in the dog. This worm does not have an intermediate stage in another animal, but is conveyed directly through the eggs produced by the female worm, which eggs normally convey the infection from a dog back to the same or another dog, either in contaminated food or water or as the result of the contamination of the skin and the subsequent cleansing of the skin by means of the tongue.

Under the conditions of unwarranted association and familiarity with dogs already mentioned, eggs of this parasite and of an allied parasite in the cat may be ingested by man, and especially by children, and subsequently develop into the adult worm in the intestine. These worms may produce unpleasant results. The entire group of ascarids are notorious for their wandering habits. They not infrequently travel to the stomach and produce vomiting, in the course of which the worms may be brought up. It is hardly necessary to say that the vomiting of worms 4 or 5 inches long is a distinctly unpleasant experience, and this is one of the least unpleasant results

of such infestation. Ascarids at times enter the appendix and cause appendicitis; they may perforate the intestine and cause peritonitis; they may come up the esophagus and get down the windpipe, with a resultant suffocation, or enter the eustachian tube of the ear. These are unusual cases for the most part, but they are dangers to be considered. There are other unpleasant and dangerous features of ascarid infestation, and the uncomfortable certainty that their presence is undoubtedly indicative of fecal contamination of food, drink, or ingesta of some sort.

The prophylaxis in this case, as in the case of the previously mentioned worms, depends on keeping dogs free from worms and restricting their privileges in the household and in their relationship to human beings.

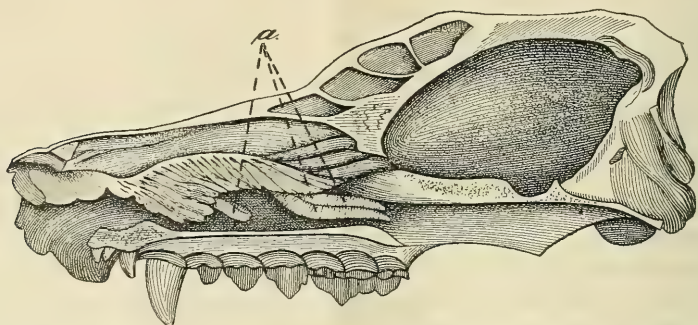


FIG. 10.—Head of a dog split in half to show three tongueworms (*Linguatula rhinaria*), *a*, in the nasal cavity. Reduced in size (after Colin).

Tongueworm.—The tongueworm, *Linguatula rhinaria* (*Linguatula serrata*) (fig. 10), occurs in the adult stage in the nasal passages and frontal sinuses of the dog. It is light colored and shows an external, ringlike segmentation. The male may attain a length of 20 millimeters (about three-fourths of an inch) and the female may attain a length of 100 millimeters (about 4 inches). The eggs deposited by the female leave the nostrils of the dog in the catarrhal secretion occasioned by the presence of the parasite, some of them doubtless being sneezed out, and contaminate the vegetation on which they at times lodge. Such vegetation may be eaten by cattle, sheep, horses, or swine, or if the infested dog has access to a truck garden or a family vegetable garden, contaminated lettuce, cabbage, etc., may be eaten by man. When the eggs get to the stomach the shell is digested off, releasing a peculiar embryo which shows by its structure that these tongueworms are really related to the mites, a group of spiderlike animals. This embryo makes its way through

the walls of the intestine and encysts in the lungs, liver, kidney, lymphatic glands, etc., where it develops to the larval stage (fig. 11). Subsequently they break out of their cysts and resume their migrations, wandering through the tissues, causing more or less damage, until they reach the abdominal or thoracic cavity, sometimes entering the intestines and bronchi, and at times causing the death of the host. Just how they get from here to the nasal passages of the dog is not very well known, though it is certain that this takes place. Possibly larvæ are at times sniffed up by the dogs as they nose through an infested carcass; possibly in eating such a carcass larvæ pass directly from the mouth of the dog back to the posterior portion of the nostril by way of the pharynx, or the parasite may return from the stomach by way of the esophagus. The adult worm has been reported, but very rarely, from the nasal passages of man.

The larvæ are apt to be overlooked in necropsies on the human cadaver, but have been recorded in as high as 25 per cent of necropsies. In various localities in Germany they are commonly present in 3 to 4 per cent. This is a widely distributed parasite, and is found from time to time in the United States. A case in man has been recorded from the Canal Zone.

Prevention consists in keeping viscera of animals away from dogs, unless the viscera are cooked, and in a reasonable attention to what a dog eats, and this involves a responsible supervision of the dog's wanderings and conduct in all respects.

FLEAS AND TICKS.

Fleas.—In the western United States investigations indicate that the commonest flea attacking man is the so-called human flea, *Pulex irritans*, of which man is the primary host. The same investigations indicate that the dog is a most important carrier of that flea, probably the most important. Of 456 fleas collected from dogs in Berkeley, Cal., 29 per cent were of this species. In the eastern United States investigations indicate that the commonest flea attacking man is the so-called dog flea, *Ctenocephalus canis* (fig. 12), and here, of course, the dog is the normal host and the usual carrier.

Either species of flea constitutes an annoying pest. The bite is distinctly unpleasant and in the summer nights may prove just the

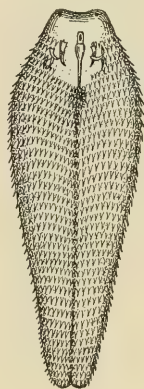


FIG. 11.—*Linguatula rhinaria*, the larval tongueworm from the liver and lymph glands of cattle, sheep, etc. Enlarged ten times (after Railliet).

additional irritant which makes sleep impossible. Equally as important as the annoyance is the fact that fleas of all sorts are under suspicion at present as possible carriers of bacteria, parasites, and diseases of various sorts. We know that the dog flea and the human flea, as well as the rat flea, are capable of transmitting bubonic plague to man; that the dog flea, as already noted, transmits the tapeworm *Dipylidium caninum* to man; and we are warranted in suspecting that additional study will add other counts to this indictment against fleas. In the meantime our actual knowledge and strong suspicion are ample grounds for avoiding fleas and the flea-bearing

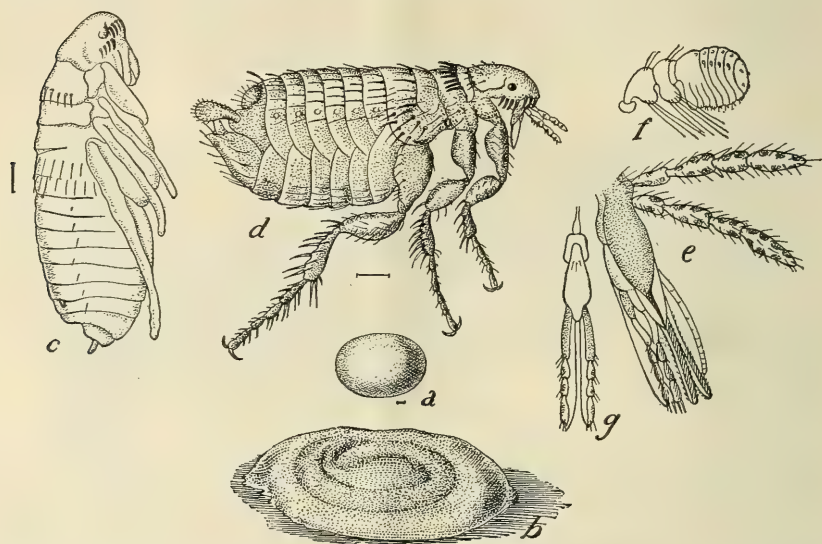


FIG. 12.—Dog flea (*Ctenocephalus canis*): a, Egg; b, larva in cocoon; c, pupa; d, adult; e, mouth-parts of same from side; f, antenna; g, labium from below. b, c, d, Much enlarged; a, e, f, g, more enlarged. (From Howard, Bureau of Entomology.)

dog. It is comparatively easy to avoid annoyance from fleas in the absence of dogs or cats around a dwelling. Where dogs and cats are present it is more difficult and the animals must be closely watched and given appropriate treatment from time to time. For adequate protection it is essential that stray dogs and dogs belonging in the neighborhood should be prevented from becoming habitual visitors and utilizing the porch and hammock as sleeping quarters.

The chicken flea (*Echidnophaga gallinacea*), a common pest in some of the Southern States, frequently infests dogs. Here, again, the remedies lie in the proper handling of dogs by their owners and the elimination of ownerless dogs or dogs whose irresponsible owners

take no care of them. Under proper conditions of restraint dogs may be rid of fleas and kept free from them.

Ticks.—In this country the dog is known to be the usual or occasional carrier of 11 species of ticks, almost all of which are also occasional or habitual parasites of man or stock. In this way the dog serves the tick by furnishing it with nourishment and also aids in spreading infestation, conveying ticks in this way to man much more effectively than other animals are able to do, for the reason that there is no other animal in such close contact with man, with so many liberties, and with such a wide and unrestrained range during the periods when it is not with its owner. These habits of the dog make it an object of suspicion in connection with tick-eradication work. Such ticks as



FIG. 13.—American dog tick (*Dermacentor variabilis*); male, dorsal view. (From Hooker, Bishopp, and Wood, Bureau of Entomology.)

Dermacentor variabilis (fig. 13), which are common on the dog, are brought into houses rather frequently and have many opportunities to attack man. Such ticks as the spotted-fever tick, known as *Dermacentor andersoni* or *Dermacentor venustus* (fig. 14), are seldom

found on dogs, but in view of the fact that the bite of one tick may result in spotted fever and the death of the person bitten, even such infrequent transmission by dogs must be guarded against. This tick is known to occur in Montana, Wyoming, Colorado, New Mexico, and the States west of these, with the exception of Arizona. Spotted fever is known to occur in a number of these States, and with the tick present its occurrence and spread in the other States depend merely on the chance of a carrier of some sort coming into them under conditions which



FIG. 14.—Rocky Mountain spotted-fever tick (*Dermacentor andersoni*, or *D. venustus*); male, dorsal view. (From Hooker, Bishopp, and Wood, Bureau of Entomology.)

will permit of the tick having access to the carrier and to other animals or persons. Dogs may also carry the Texas-fever tick (*Margaropus annulatus*), and some species of ticks possibly depend on the dog for their continued existence.

Dogs which are kept free of such vermin as ticks by frequent baths or other necessary measures and which are not allowed to wander at will are reasonably safe from the standpoint of spotted fever or other tick conveyance to man or stock. They are at least much safer than those which are neglected, allowed to accumulate internal and external parasites, and to carry and convey the same without hindrance.

MISCELLANEOUS PARASITES.

In the foregoing part of this paper only those injuries, parasites, and diseases traceable to the dog which are known to occur in the United States have been mentioned. It should be stated, however, that the dog is known to have quite a large number of other parasites, some of them already present in this country, which have been found in man and stock in foreign countries, sometimes as rare and unusual occurrences and sometimes very common and even in the form of endemic, constantly present diseases. Inasmuch as almost all of the parasites heretofore mentioned originated in foreign countries and were brought here, and since we have no guaranty and but little protection against others being brought here, it will be worth while to name some of the other parasites of which space forbids a detailed discussion. Some of the parasites mentioned below have been found in the dog only as a result of experimental infestation, which is, however, proof that they might occur in nature under suitable conditions of transmission. Some of these diseases, owing to the nature of the life history, possibly could not obtain a foothold in this country, but many of them certainly could.

Protozoa.—The dog has been reported as a carrier of the following protozoa: *Entamæba dysenteriae*, the cause of amebic dysentery in man; *Lambliæ intestinalis*, a flagellate protozoan which is rather common in man in the United States; *Trypanosoma evansi*, which is the cause of surra, a disease of horses, cattle, etc., which has not yet been introduced into this country, but which has been detected at the quarantine station and kept out of the country by the United States Bureau of Animal Industry on one occasion; *Trypanosoma brucei*, which is the cause of nagana, a disease of horses, cattle, etc., which occurs in Africa; *Trypanosoma equinum*, which is the cause of mal de caderas, a disease of horses in South America; *Trypanosoma dimorphon*, which causes a disease of horses, cattle, etc., in Africa; *Trypanosoma pecaui*, which is the cause of baléri, a disease of horses in Africa; *Nuttallia tropica*, which is the cause of a piroplasmosis of horses and cattle in India; *Leishmania furunculosa* (*L. tropica*), which is the cause of Oriental sore, a disease of man which has recently been reported from this continent at Panama;¹ *Leishmania*

¹ Oriental sore in Panama. By S. T. Darling. Arch. Int. Med., Chicago, v. 7, May, 1911, pp. 581-597.

infantum, which is the cause of infantile splenomegaly, a serious, commonly fatal disease of children in Italy and Tunis; *Leishmania donovani*, which is the cause of tropical splenomegaly, a serious disease of adults in India, China, and the Sudan; *Leishmania braziliensis*, which is the cause of a disease of man in South America; *Spirochæta aboriginalis*, which is the cause of granuloma inguinale in man in British Guinea and Australia; and of some other protozoan forms of which the record or the identity of the form in the dog with those in man or stock is still uncertain. A useful object lesson may be drawn from the fact that the destruction of stray dogs in one small island in Italy has resulted in a remarkable reduction in the prevalence of infantile splenomegaly in that locality. This terrible disease is apparently spread from dogs to children by fleas.

In addition to the above-mentioned protozoa there are a number of worm and arthropod parasites carried by the dog and attacking man or the domestic animals, which have not been discussed in the first part of this paper because of their absence from or comparative infrequency or unimportance in this country. A brief note of these forms is given here.

Tapeworms.—As regards tapeworms, the dog shares with man the responsibility for carrying the broad fish tapeworm, *Diphyllobothrium latum* (*Dibothriocephalus latus*), a tapeworm of considerable medical importance, which is known to be established in this country, and both carry an allied tapeworm, *Diphyllobothrium cordatum*. The dog is also an occasional host of the pork measles parasite (*Cysticercus cellulosæ*), the larvæ of one of the tapeworms of man. The dog becomes infested with this parasite by eating the feces of the human host of the tapeworm. It has also been shown to act as the host of an adult tapeworm having a *Sparganum* larva in the hog, and may be the host of other related tapeworms belonging to this group.

Flukes.—The dog is reported as the carrier of the following flukes: *Paragonimus kellicotti*, which occurs in the lungs, causing parasitic hemoptysis in hogs in this country; *Clonorchis sinensis* and *Clonorchis endemicus*, which occur in the liver of man and hogs in China and Japan; *Heterophyes heterophyes*, which occurs in the intestine of man in Japan and Egypt; *Dicrocoelium dendriticum* (*D. lanceatum*), which occurs in the bile ducts of man and of horses, cattle, sheep, hogs, etc., and which is common in various foreign countries, though not as yet known from the United States; *Schistosoma japonicum*, which occurs in the blood of man in Japan, China, the Philippines, and South Africa; *Opisthorchis felinus*, which occurs in the liver of man in Asia; and of *Opisthorchis novercæ* and *Pseudamphistomum truncatum*, also parasites of man.

Nematodes.—As regards nematodes, the dog is one host of *Dracunculus medinensis*, the Guinea worm, which is not known in this

country, and is the usual host of *Diocetophyme renale*, the giant kidney worm, which is a huge red worm a yard long and as thick as a little finger, occurring in the kidney or abdominal cavity of man, the cow, the horse, and the hog. This last-named worm has been found in this country on a number of occasions. *Strongyloides stercoralis*, the parasite of Cochin China diarrhea, can be readily transmitted to dogs, and a *Strongyloides*, apparently this species, is found in dogs in China and Japan.

Mites, fleas, etc.—The dog is affected by a form of mange or scab due to a mite known as *Sarcoptes scabiei canis*. This disease occurs in this country and may be transmitted to man, causing more or less discomfort. The dog is also known to be attacked by and transmit the sarcoptic scab of sheep, a rather rare form of scab due to the mite *Sarcoptes scabiei ovis*.

In addition to being the adult host of the aberrant spiderlike form, *Linguatula rhinaria*, the larva of which may occur in man, the dog is a host for the larval form of two closely related species, *Porocephalus armillatus* and *P. moniliformis*, which may also pass their larval stage in man.

The dog is not only a host for the cosmopolitan fleas *Pulex irritans* and *Ctenocephalus canis*, but is also a host for the widely distributed chigger flea, or chigoe, *Dermatophilus penetrans* (*Sarcopsylla penetrans*), of tropical countries and native in the southern portion of North America. This flea attacks men, cattle, horses, mules, sheep, goats, and hogs, the female becoming embedded in the skin and growing to the size of a pea.

Finally, the dog is an important host of the parasitic larvæ of certain flies which also habitually attack human beings and live stock. One species, *Dermatobia cyaniventris*, occurs in South and Central America, and another, *Cordylobia anthropophaga*, occurs in Africa. These larvæ undergo their development beneath the skin, causing boil-like tumors and abscesses. Another species, *Paralucilia macellaria* (*Chrysomyia macellaria*), is a serious pest in the southern United States. Its larvæ, commonly called screw worms, attack cattle, horses, and other animals, including dogs and human beings. These screw worms may undergo their development in the carcasses of dead animals as well as in the tissues of live animals.

CONCLUSION.

The parasites discussed in this paper do not nearly exhaust the list of those present in the dog, but only those known also to affect man or live stock.

In conclusion it may be said that the dog is at present the subject of numerous criticisms from three quarters. For over half a century

parasitologists have been insisting that the dog is so largely responsible for the spread and so essential to the existence of so many important parasites that we must curtail his liberty and guard him, ourselves, our families, and our stock from the evil results of his unrestrained wanderings.

For a number of years public-health officers and others who have the welfare of the community at heart have been insisting on a restriction of the dog's unwarranted liberty in order to lessen and in time to eliminate the terrible menace of rabies.

More recently the sheepmen who have been accustomed to keeping out of business in localities where there were too many dogs, or who have permitted themselves to be forced out of business as a result of the attacks of sheep-killing dogs and the resentment and antagonism of the dogs' owners, have been taking more aggressive action and have started a propaganda looking toward the elimination of the worthless dog and the placing of full responsibility for other dogs on their owners.

It is to be hoped that the coordinate action of these persons and others interested in the safeguarding of life, health, and property will soon bring about positive and valuable results.

In a general way there are three kinds of dogs—the vagrant, ownerless stray; the other person's dog; and your own dog.

The stray dog which recognizes no owner must be eliminated. The irresponsible dog with no owner to care for him, to look after his health as it concerns the dog and other animals and man, and to restrain him and stand sponsor for his acts and especially the damage he may do—such a dog does not fit into a scheme of civilization which is based on law and the responsibility of individuals for themselves and others.

We have a right to insist, and should insist, that the other person's dog keep off our premises. A dog that is allowed by the owner to wander at large will have substantially the same habits of life, the same sort of food, and be substantially as dangerous as the ownerless dog. Such a dog is not only a trespasser but a potential menace whose visits may incur loss of money, health, or even life.

Your own dog should be handled in such a way as best to further the welfare of the dog and the community. He should be kept in restraint and not allowed the full freedom of the house or even of the outside premises. He should not be allowed to be familiar with people, and especially with children. The dog should be kept free from external parasites by frequent baths and, if necessary, other appropriate measures, and should be freed from internal parasites by suitable measures and kept free by adequate attention to his food. He should only be allowed to leave the yard or the kennels in company

with some person, and wherever conditions call for it should be kept in leash. When away from home the dog should be muzzled with a reliable metal muzzle, not with a strap muzzle that would be cruel to the dog if tight enough to be effective and which is usually so loose as merely to give a false sense of security, since it permits the dog to bite.

In regard to laws requiring muzzling and other restraints, Schroeder¹ has made the following interesting comment:

The reason why laws of this nature have not been made is due to the active fight against them by a small, greatly interested minority that opposes a tardy, disinterested majority. The minority fights hard for a privilege it has long enjoyed and abused, that of allowing dogs to be at large without restraint at all times, and the majority has never half realized that this privilege is costing a high price in the destruction of property and in horrible agony and numerous deaths. * * * The dog owner who knows what rabies is from experience, if he has the proper consideration for his own welfare and that of his dogs, will be among the first to demand a movement for its suppression, even if this should place restrictions on the freedom of his own dogs. His interest is greatest because he has the most at stake and is himself most seriously and frequently exposed to the infection.

As means or adjuncts for attaining the conditions outlined here, numerous measures have been suggested and, to some extent, practiced in this country. Some of these measures are cited in a paper by Stimson,² and a very good summary has been given by him. Among the possible measures are, of course, the imposition of a license on all dogs, dogs so licensed to wear an official tag with at least a registered serial number on it, and possibly with the owner's name and address also. Any dog not so licensed should be taken up by an adequate impounding force and humanely killed. Dogs so licensed should be taken up when found astray in violation of ordinances requiring muzzling or imposing other restrictions. Rabies should be made a reportable disease everywhere, and prompt and thorough measures taken for its eradication, to be followed by quarantine against unrestricted importation of dogs into clean areas. Castration and spaying are recommended as aids in keeping a dog at home. They also serve to stop the promiscuous breeding which serves to add recruits to the vast army of worthless and vagrant dogs. Dr. Arbuckle, in recommending castration, says that it does not diminish the animal's value as a hunting dog.

Protection from the dangers of improperly controlled dogs depends primarily on the education of the public and the development of an educated public sentiment. With public sentiment behind it any re-

¹ Some observations on rabies. By E. C. Schroeder. Bureau of Animal Industry Circular 120. 1908.

² Facts and problems of rabies. By A. M. Stimson. Hygienic Laboratory Bulletin 65, 1910.

form is possible; without it practically nothing is possible. Undue sentiment for the dog should not be allowed to blind us to his dangerous possibilities as a carrier of diseases and parasites or to stand in the way of effective measures for the protection of human life and health. The time seems to be at hand when the stray dog, the sheep-killing cur, the vagrant carrier of dangerous parasites and of the horrors of rabies should be exterminated. The destruction of such dogs would mean a saving of hundreds of lives and the saving and making of millions of dollars.

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July 19, 1915.

(PROFESSIONAL PAPER.)

AMERICAN PLUM BORER.¹

By E. B. BLAKESLEE, *Entomological Assistant, Deciduous Fruit Insect Investigations.*

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INTRODUCTION.

In the summer of 1912, while engaged in deciduous fruit insect investigations at Winchester, Va., the writer's attention was attracted by the common occurrence upon apple of the American plum borer, *Euzophera semifuneralis* Walk. Although injury to fruit trees by the larvæ of this insect was recorded by Forbes in Illinois as early as 1890, very little has since been published concerning it. This lack of attention may be attributed to the fact that though common and widely distributed it has never occurred in sufficient numbers or been sufficiently destructive to call upon it any special notice as an economic species.

The food habits of this insect are particularly interesting when contrasted with those of other wood-boring species. It is also an insect that under certain conditions is capable of doing considerable damage to trees which have been injured either mechanically or by the attacks of fungous diseases. At the suggestion and under the direction of Mr. A. L. Quaintance, of the Bureau of Entomology, an attempt was made, therefore, in the summer of 1913 and 1914, to study the insect's biology.

For the photographs presented in this paper the writer is indebted to Mr. Fred E. Brooks, of the Bureau of Entomology.

¹ *Euzophera semifuneralis* Walk.; order Lepidoptera, family Pyralidae.

HISTORY.

This species was first described by Walker, in 1863, under the name of *Nephopteryx semifuneralis*. In 1881 Zeller redescribed and figured it as *Euzophera impletella*. In 1887 Hulst described the species as *Stenopterycha pallulella*. In 1889 we find the first published reference to the immature stages of this insect; S. A. Forbes, in his report for that year, described the larvæ as injuring Chinese plum (*Prunus simoni*) in Illinois. Forbes gave it the common name of American plum borer. In 1891 D. S. Kellicott reported it as injuring mountain ash in Ohio, and in 1898 Otto Lugger included it in a list of "Butterflies and Moths Injurious to our Fruit Producing Plants." In 1901 E. D. Sanderson reported it as injuring apple and Kieffer pear in Delaware, giving a few notes on its probable life history in that locality and renaming it the "fruit-tree bark borer." Slingerland and Crosby have given a short account of this borer in their recent "Manual of Fruit Insects."

While Forbes's report is the first published reference to the feeding habits of the larvæ of this insect, we find in the unpublished notes of the Bureau of Entomology, February 2, 1879, the following note: "Received from E. A. Schwarz, Jackson, Miss., one cocoon found under bark on fence around cotton field. The moth issued and proves to be either *M. distinctella*, or one that comes very near to it." This specimen was later determined by H. G. Dyar to be *Euzophera semifuneralis* Walk. Again, May 14, 1879, in the notes of the Bureau of Entomology, Theo. Pergande records finding a cocoon on peach and rearing a moth belonging to the Pyralidæ, which he names rather doubtfully *Acrobasis* sp. A later determination by Dyar proved this also to be *Euzophera semifuneralis*.

DISTRIBUTION.

Dyar gives the distribution of this borer as "United States." Zeller described the species in 1881 from four specimens from Colombia, South America, one of which was taken at Mariquita on August 10 and the other at Honda the last of April. Hulst notes that his description was based on specimens from New York, Utah, and Washington. In the United States, specimens in the collection of the United States National Museum, and the correspondence, notes, and collection of the Bureau of Entomology, as well as the literature available, indicate that the insect occurs in the following States: Arkansas, Arizona, Colorado, Delaware, Florida, Georgia, Illinois, Indiana, Kansas, Missouri, Maryland, Mississippi, North Carolina, New York, Ohio, South Carolina, Texas, Utah, Virginia, West Virginia, Washington, and the District of Columbia.

FOOD PLANTS.

This insect does not, by any means, confine its attacks to plum. It has been taken feeding upon plum, peach, cherry, Chinese plum (*Prunus simoni*), Kieffer pear, mountain ash, persimmon, apple, and Russian mulberry. The writer has found it equally abundant on plum, cherry, peach, and apple. It will probably attack the trees of any of the common stone or pome fruits when the proper conditions are presented.

FEEDING HABITS AND CHARACTER OF INJURY.

As has already been stated, the food habits of this insect are of especial interest when contrasted with those of other wood-boring species. The plum borer prefers trees which are not dead and yet are not in a too vigorous condition. The attention of the writer was first attracted to the work of this borer by an apple tree upon which it had established itself. This tree had been partially girdled by a disease commonly known as collar blight. Under the skirt of bark bordering the wounded area the borer had begun its work and by extending its galleries out into the living tissue had completed the girdling of the tree. This seems to be the characteristic form of injury for the species. Beginning at some scar, wound, or crevice, where a bark scale offers partial protection, the larva works its way back into the living tissue, in broad, shallow, irregular galleries just beneath the bark. Apple trees partially girdled by collar blight and trees injured mechanically by frost or by some other factor offer the ideal condition for the work of this borer. Without injury of some sort to its host plant the borer rarely succeeds in establishing itself, and entirely healthy and uninjured trees are in little danger from its attacks. On the other hand, where a tree has suffered injury the work of this borer may, in many cases, considerably shorten its life. Pl. I, *a*, *b*, *c*, shows the character of the galleries and the condition of trees most liable to attack.

DESCRIPTION OF STAGES.

THE EGG.

When first deposited the egg appears as a regular oval, opaque white body, coarsely punctate. The size is fairly uniform, the average for 10 being 0.59 mm. by 0.42 mm. A marked change takes place in the appearance of the egg as incubation proceeds. Twenty-four hours after deposition the color changes from white to a pinkish tint, or in cases where incubation is somewhat delayed to a light brown, and in 48 hours to a dull red. In three to four days a slight depression appears in the center and 24 hours before hatching the color

changes to a dirty white with the head of the larva plainly visible at one end. The unfertilized egg remains white. After hatching the shell is white and retains its shape. The eggs are deposited singly or in small irregular groups, usually in cracks or crevices of the bark, or in the absence of such places they are rather insecurely glued to smooth surfaces (Pl. II, *e*). They are easily broken away from the surface to which they are attached.

THE LARVA.

In leaving the egg the larva (Pl. II, *b*) gnaws out an irregular hole in one end and leaves the shell in two or three minutes. The newly-hatched larva is very active; its color is white throughout with the exception of the very large dark brown head, and the alimentary tract which shows plainly from its reddish coloration. After a few days of feeding the color of the body changes to a dingy white and later to a brownish green, somewhat lighter on the ventral surface. The full-grown larva averages about 25 mm. in length by 3 mm. in width. The head is dark brown; the cervical shield, pale yellow, with black markings on either side. The anal plate is brown and the thoracic legs are light brown with darker tips. There is great variation in the color and size of individual specimens.

THE PUPA.

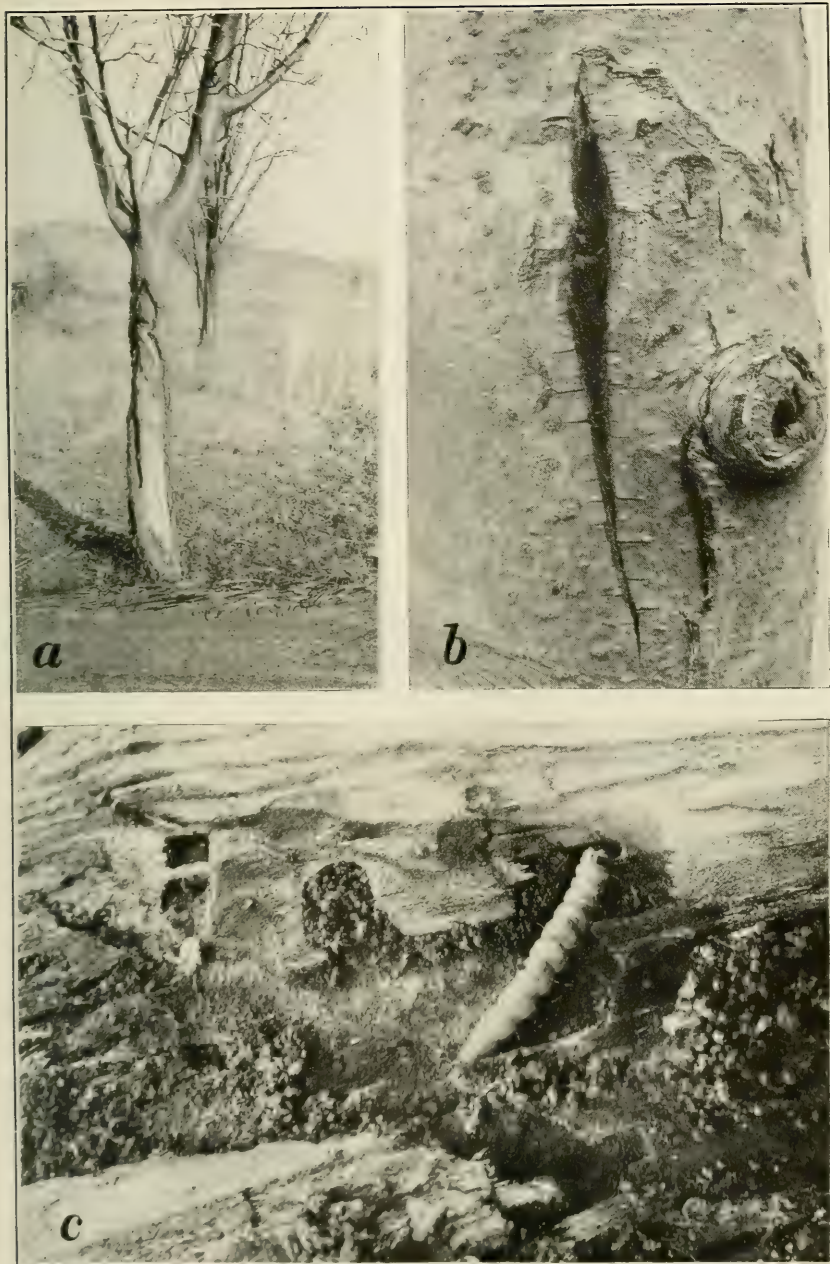
When first formed, the color of the pupa (Pl. II, *f*) is light olive green, which changes in one or two days to light brown and 24 hours before emergence to dark brown and then black. The size is variable, but averages about 10 mm. by 3 mm. The wing sheaths are somewhat lighter brown and extend about two-thirds of the total length of the body. The eyes are black, the spiracles well defined, and the last abdominal segment has a variable number of stout hooked spines.

THE ADULT.

The adult female (Pl. II, *a*) measures about 1 inch across the expanded wings. The average measurements of 10 specimens were: Spread of wings, 19.5 mm.; length of body, 8.4 mm.; width of body, 1.4 mm. The head, thorax, legs, and abdomen are a light gray. The fore wings are grayish brown with a broad, wavy band of black and brown markings across the outer third. There is considerable variation in the color pattern of the fore wings, however, and frequently these markings are almost or entirely absent. The hind wings are smoky with a distinct black marginal line.

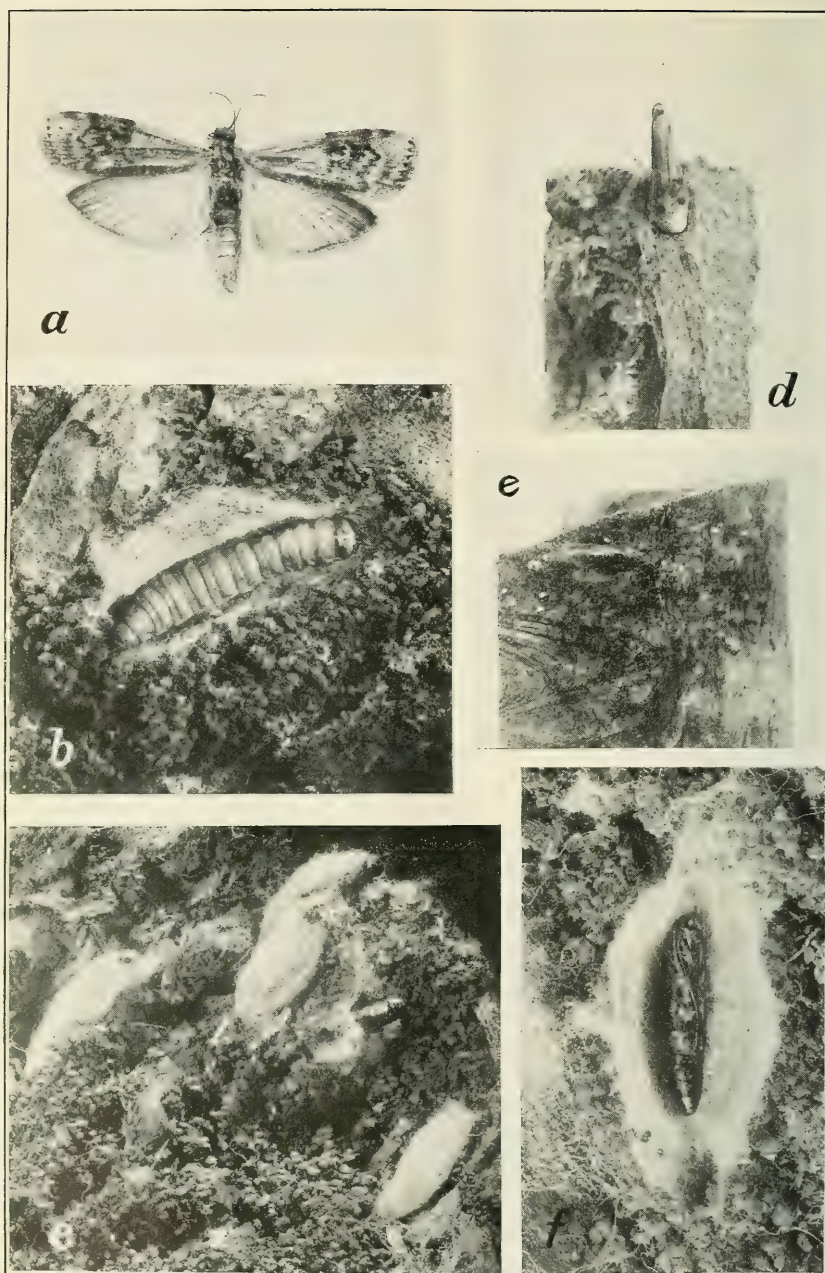
The insect was first described by Walker in 1863. The following is his description:

Nephopteryx semifuneralis n. s. *Female*, blackish cinereous, dingy cinereous beneath. Palpi smooth, slender, hardly curved, obliquely ascending, not rising higher than the



WORK OF THE AMERICAN PLUM BORER (*EUZOPHERA SEMIFUNERALIS*).

a, Plum orchard in which the trunks of the trees are being injured by the plum borer; *b*, crack in bark of apple tree through which larvæ of the plum borer entered; *c*, galleries and young larva of the plum borer. (Original.)



THE AMERICAN PLUM BORER.

a, Adult, about twice natural size; *b*, winter cocoon opened to show larva, enlarged about one-half; *c*, mass of winter cocoons embedded in frass and silk under scale of cherry bark; *d*, characteristic resting posture of adult; *e*, eggs, about natural size; *f*, cocoon opened to expose pupa, about twice natural size. (Original.)

vertex; third joint lanceolate, nearly as long as the second. Abdomen extending beyond the hind wings; hind borders of the segments pale cinereous; wings moderately broad; fringe long, cinereous. Fore wings hardly acute; middle and exterior lines cinereous, undulating, blackish-bordered; discal mark cinereous, curved; marginal points black; exterior border convex, hardly oblique. Hind wings dark cinereous, very slightly hyaline; marginal line brown. Length of the body 5 lines; of the wings 12 lines.

a. North America. From Mr. Carter's collection.

SPRING PUPATION OF WINTERING LARVÆ.

At Winchester, Va., in the spring of 1913, pupation of the wintering larvæ began about the last of March to the first of April. Frequent collections of larvæ were made previous to and including March 24, and pupation had evidently not begun up to that time. Absence from Winchester prevented further observation for a period of 14 days following March 24, and during this interval, of the 31 larvæ that had been taken in the field previous to that date, 18 had pupated by April 7. However, the temperatures from April 4 to April 7 were so extremely low that insect life generally was almost dormant and most of this pupation must have occurred before the former date.

Girault in 1906 records the pupation of three larvæ under his observation in the insectary at Washington, D. C., as occurring on March 27, 28, and 31, respectively. At Myrtle, Ga., in the same year, both Rosenfeld and Girault observed pupation as early as March 2, or about 25 days earlier than in the latitude of Washington. Girault, in 1905, took four pupæ in the field at Myrtle, Ga., March 1. In the latitude of northern Virginia and the District of Columbia, in a normal season, pupation evidently begins about April 1 or possibly a little before, depending upon the relative lateness of the season, and as far south as Georgia probably a month earlier.

The 23 individual records of the pupal stage included in Table I were taken from field-collected material kept in an out-of-doors rearing shelter. In most cases the larvæ under observation were kept in their winter cocoons (Pl. II, *c*), which are so loosely woven that the transformation of the insect within can be easily seen. Occasionally it was necessary to force the larvæ to spin up in glass vials, but this was avoided as far as possible, as the insect under such conditions probably does not feel the full effect of the changes in outside temperature.

TABLE I.—*Length of pupal period of wintering larvæ of the plum borer, Winchester, Va., 1913.*

No. of observation.	Date of—		Length of pupal period.
	Pupa-tion.	Emer-gence.	
			<i>Days.</i>
1	Apr. 14	May 17	33
2	14	15	31
3	17	15	28
4	19	16	27
5	19	21	32
6	22	21	29
7	24	18	24
8	24	21	27
9	24	21	27
10	24	21	27
11	25	24	29
12	25	27	32
13	25	27	32
14	26	27	31
15	26	27	31
16	May 2	27	25
17	2	27	25
18	4	June 2	29
19	4	May 30	26
20	5	June 2	28
21	6	2	27
22	6	2	27
23	7	3	27
Maximum			33
Minimum			24
Average			28.43

The longest pupal period observed was 33 days, the shortest 24, and the average of the 23 observations 28.43 days. The records at Winchester show a slightly longer duration of this stage of the insect's life than has been observed by others, though data from other sources are rather limited. Girault, in 1905, notes that one larva pupated in the insectary at Washington March 28 and emerged April 21, a period of 24 days, while Rosenfeld, at Myrtle, Ga., in 1906, reports one insect that transformed from larva to adult in 20 days. Fred Johnson, at Youngstown, N. Y., in 1905, has the following note: "Larvæ confined in jar form cocoons June 28. Adults emerged from these July 20 and others continued to appear until August 4." Evidently some of the insects in this instance transformed in less than 23 days. The weather conditions of the spring of 1913 may be partially the cause of the longer pupal period at Winchester, the unusually high temperature prevailing through March hastening the insect's pupation, while the relatively cold April that followed probably delayed the emergence of moths.

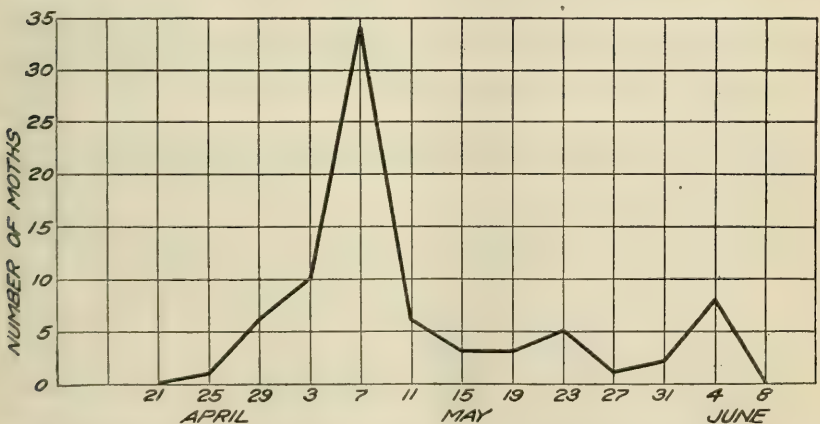
EMERGENCE OF SPRING BROOD OF MOTHS.

Table II gives in detail the time of appearance of 79 moths that emerged at Winchester in the spring of 1913 from field-collected rearing material. The first adult appeared in the laboratory on April 25 and by the fore part of May the insect was emerging in numbers.

TABLE II.—Emergence of spring brood of moths of the plum borer at Winchester, Va., in 1913. (See fig. 1.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
Apr. 25	1	May 19	3
29	6	23	5
May 3	10	27	1
7	34	31	2
11	6	June 4	8
15	3	8	0
		Total..	79

Girault, in 1905, records one adult that emerged at Washington as early as April 21 and later notes that empty pupal cases were very plentiful in the field by May 2. In normal seasons adults probably begin appearing in the latitude of Winchester and Washington from the last of April to the first of May. Rosenfeld, in 1906, observed emergence in Georgia as early as March 29, or about one month earlier than it occurred at Washington the preceding year. In 1913 maximum emergence occurred at Winchester on May 7, twelve days after the first moth appeared, and adults continued to emerge in the rearing cages in lessening numbers until June 4. The seasonal appearance of the moths can be more easily appreciated by reference to figure 1.

FIG. 1.—Diagram showing emergence of spring brood of moths of the American plum borer (*Euzophera semifuneralis*) at Winchester, Va., in 1913. (Original.)

OVIPOSITION OF FIRST GENERATION OF MOTHS.

As the moths emerged from day to day they were transferred to jars containing twigs of plum or apple wood, all of those issuing on the same date being confined in one jar and a record kept of the number of eggs subsequently deposited. Eggs were laid freely on the twigs, singly or in small groups in the cracks and crevices of the

bark, or very often were rather insecurely glued to the sides and bottom of the jar as well.

From Table III it will be seen that the moths began to oviposit in from 1 to 3 days after emergence, the average for seven observations being 1.7 days. On the average, oviposition lasted 2.3 days, the longest period observed being 4 days and the shortest 1 day. Girault records three moths that oviposited in confinement in the insectary at Washington, May 8, 1905, the duration of oviposition being 2 days.

TABLE III.—*Oviposition of the spring brood of moths of the plum borer, Winchester, Va., 1913.*

No. of cage.	Number of moths.	Date of—			Days—		
		Emergence.	First oviposition.	Last oviposition.	Before oviposition.	Of oviposition.	From emergence to last oviposition.
1	6	Apr. 26	Apr. 29	May 2	3	4	7
2	5	May 2	May 3	6	1	4	5
3	3	3	6	6	3	1	4
4	8	4	5	6	1	2	3
5	5	5	7	7	2	1	3
6	2	5	6	7	1	2	3
7	6	6	7	8	1	2	3
Maximum.....					3	4	7
Minimum.....					1	1	3
Average.....					1.7	2.3	4

Copulation was never observed, but evidently occurred very soon, since in several instances fertile eggs were deposited within 24 hours of emergence. In the absence of the male the female deposits infertile eggs freely.

The number of eggs deposited in confinement per female is indicated in Table IV.

TABLE IV.—*Number of eggs of the plum borer deposited per female in confinement, Winchester, Va., 1913.*

Date.	No. of females under observation.	Number of eggs.	
		Deposited.	Deposited per female.
April 26	1	45	45
May 2	2	50	25
3	2	24	12
5	1	74	74
Average.....			32.2
Maximum.....			74
Minimum.....			12

Records were kept of the number of eggs laid, in two jars containing 2 females each and in two jars containing 1 female each. The

condition of the moths in confinement is of course quite unnatural. The greatest number of eggs laid by one female was 74. In one instance only 24 eggs were deposited in a cage containing 2 females and the minimum is stated as 12, although it is of course possible that only one female was ovipositing.

Girault, May 8, 1905, gives a record of three adults, emerging in the insectary at Washington, that deposited 78 eggs, an average of 26 eggs each. No observations were made in the field that would throw any light on this part of the insect's life cycle.

LENGTH OF LIFE OF MOTHS OF SPRING BROOD.

The length of life of 17 adults is given in Table V.

TABLE V.—*Length of life of moths of the spring brood of the plum borer, Winchester, Va., 1913.*

No. of moths.	Length of life.	No. of moths.	Length of life.
	<i>Days.</i>		<i>Days.</i>
1	3	2	11
1	4	1	12
2	6	2	13
1	7	2	15
1	8	1	18
1	9	1	23
1	10		
Total		17	139
Maximum			23
Minimum			3
Average			8.2

These moths were supplied with sweetened water. Several cages of moths were given nothing in the way of food or water and several were given water alone. The observations were too limited to justify the drawing of any conclusions as to the influence on longevity of sugar and water compared with water alone, but those given neither, as a rule, lived only a few days after oviposition.

The moths fed upon sweetened water lived from 3 to 23 days, the average of 17 observations being 8.2 days. No data were obtained upon the relative longevity of the sexes.

HABITS OF THE MOTHS.

When resting the moth assumes the characteristic position seen in Plate II, figure *d*, the wings tightly folded, the legs pulled in closely and set far back under the abdomen. The rigid posture of the body and the blending of the ashy grays and dark browns of the forewings produce to the human eye at least a close resemblance to a short twig. During the day the moths remain in this posture for hours at a time, and until the eye has become accustomed to this

adaptation of the insect they are easily overlooked in the rearing cages.

As a rule the moths are rather inactive during the day, though egg laying is by no means entirely limited to the hours of darkness. The moths are evidently active at night. Forbes (1890) records taking them at night in Illinois.

INCUBATION OF FIRST-BROOD EGGS.

Table VI shows the incubation period of first-brood eggs.

TABLE VI.—*Incubation period of first-brood eggs of the plum borer, Winchester, Va., 1913.*

Number of eggs observed.	Date—		Period of incubation.
	Deposited.	Hatching.	
36	Apr. 29	May 7	Days. 8
3	May 2	10	8
8	3	11	8
11	4	12	8
32	6	19	13
38	7	21	14
19	8	21	13
Average.....			10.3

The shortest incubation period observed was 8 days, the longest 14, and the average for seven lots of eggs was 10.3 days. The long incubation required by the three lots of eggs deposited on May 6, 7, and 8, respectively, is entirely due to the cold wave of May 8, 1913. The temperatures were so extremely low that incubation very probably ceased altogether. The 8-day period required by the first four lots of eggs probably represents more nearly the average incubation period under seasonable temperature conditions. As a rule the incubation period for the individual eggs of a given lot varied only a few hours, and in recording observations for any lot of eggs incubation was considered over when the first egg hatched.

FIRST-BROOD LARVÆ.

An attempt was made to rear larvæ at Winchester on plum wood. A number of old plum trees were transplanted in May to the vicinity of the laboratory. As the larvæ hatched they were transferred to these trees. All began feeding at once. Unfortunately predaceous enemies and parasites destroyed all but one of these larvæ before they reached maturity. This larva hatched on May 7, from the first lot of eggs obtained in the laboratory, spun up on June 10, pupated June 12, and emerged June 22. The feeding period in this case was 34 days; the prepupal period, 2 days; the pupal period, 10 days.

Two pupæ taken in the field on July 14, which from their light olive-green color had just transformed, emerged on July 22, indi-

cating a pupal period in this case of 8 days. Another mature larva taken in the field pupated in the laboratory on July 18 and emerged July 30, giving a pupal period of 12 days. Two moths emerging in the laboratory on July 22 deposited eggs the following day.

A second generation, or, at least, a partial one, occurs in the latitude of Winchester. As just stated, one adult emerged on June 22, from a larva which hatched in the laboratory on May 7. The indicated life cycle for the first generation is as follows: Incubation, 10 days; feeding period, 34 days; prepupal period, 2 days; pupal period, 10 days; from emergence to egg laying, 1 day; entire length of life cycle of first generation, 57.3 days.

Apparently eggs of the first generation begin hatching in the fore part of May and of the second generation about July 1. Whether all of the first-brood larvæ transform to moths the same season is not apparent from the information at hand. It seems fairly certain, however, that there is at least a partial second generation. There is evidently considerable overlapping of the two generations. Adults are emerging more or less throughout the summer and it is possible to find at almost any time larvæ of all sizes. Pergande, in 1898, records rearing one moth in the insectary at Washington from a larva sent to him from Anderson, S. C., as late as October 24, and the writer has observed newly hatched larvæ at Winchester September 28.

HIBERNATION.

In the late fall the larva constructs, under the bark scales at the entrance to its feeding galleries, a loose, light, but very tough cocoon of white silk. To the outside of this are often fastened frass and small pieces of bark. Numerous observations in the seasons of 1912 and 1913 indicate that many of the larvæ go into the winter in an immature state, yet in the spring of 1913 no evidences of feeding were found among about 100 larvæ collected in the field. All of the undersized specimens, of which there were a considerable number, proved to be parasitized. In 1912 newly hatched larvæ were found in the field as late as September 28, and in favorable years immature larvæ may succeed in passing the winter successfully in northern Virginia. In the writer's opinion, however, the mortality due to winter killing among the immature larvæ must be very high in this latitude.

When disturbed or exposed to the light the larva leaves its winter cocoon and spins up in a more protected place. However, as a rule, unless disturbed or unless the winter cocoon is located in an unsatisfactory place, the larva pupates in the same cocoon in which it passes the winter. Larvæ have never been observed passing the winter as "free larvæ," even parasitized specimens spinning a cocoon. In fact, even during the summer months the insect usually threads a light shelter at the end of its burrow where it rests when not feeding.

NATURAL ENEMIES.

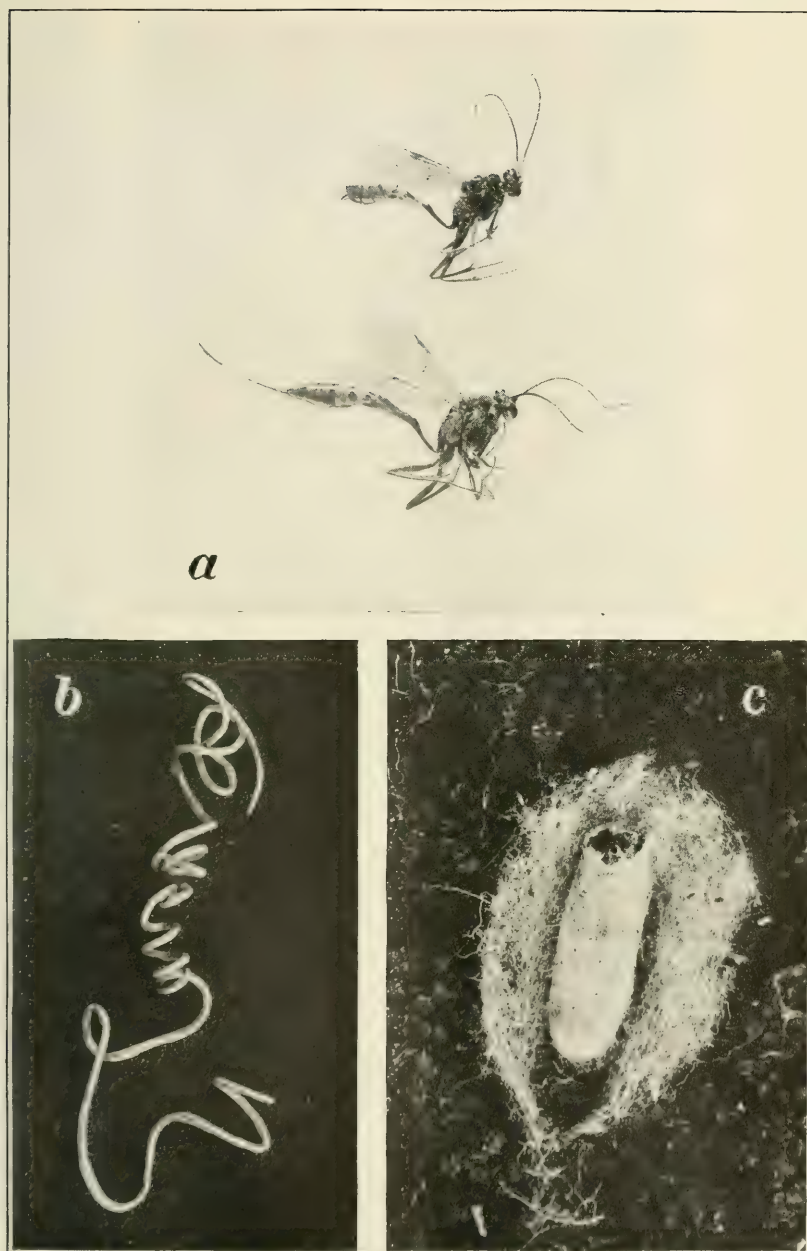
The larvæ of *Euzophera semifuneralis* are attacked by a number of parasitic and predaceous enemies. Two parasitic forms were reared at Winchester in 1913, which were determined by Mr. R. A. Cushman, of the Bureau of Entomology, to be *Idechthis* sp. (Pl. III, a) (Quaintance No. 10402) and *Mesostenus thoracicus* (Cress.). The former was by far the more common. Of 104 overwintering larvæ collected in the field 14 were parasitized by this insect. This proportion of parasitized specimens, amounting to 13.47 per cent, indicates that the parasite may aid very materially in the control of the borer. The parasitized larvæ are about one-half normal size and usually lack the greenish-brown color of healthy specimens. At some time during the prepupal period the parasite matures, devours the larva, and spins its cocoon (Pl. III, c). Fred Johnson, in 1905, at Youngstown, N. Y., reared an undetermined member of the family Ichneumonidæ (Quaintance No. 574). J. H. Beattie, in 1905, at Fort Valley, Ga., reared from borer larvæ *Itoplectis marginatus* (Prov.), *Mesostenus gracilis* Cress., and *Pimpla* sp. (Quaintance No. 399).

Mr. Fred E. Brooks, of the Bureau of Entomology, records rearing a hairworm, probably a species of *Mermis* (Pl. III, b), from larvæ of the plum borer.

Among the predaceous enemies the larva of *Tenebroides corticalis* Melsh. has been taken feeding upon the borer. Ants and woodpeckers are also important factors in reducing the numbers of this insect.

REMEDIAL MEASURES.

As has already been stated, the plum borer will probably never become a pest of more than ordinary importance, except in occasional isolated cases. Its food habits are such that it is entirely unable to establish itself upon vigorous, healthy, uninjured trees. However, in common with a number of other insects it does deserve some attention on account of its ability to do considerable real injury where the proper conditions are presented, i. e., where trees have been injured by hail, frost, or attacks of fungous diseases, and its rather indiscriminate choice of food plants increases its opportunities in this direction. One of the most common instances of this in the observation of the writer is in the case of the collar blight of apple, where the injury done by this disease is frequently supplemented by subsequent attacks of the plum borer. When the ordinary precaution of cutting away the dead bark and painting the wounded areas is followed, this may be regarded as sufficient for the control of the borer. Where the borer has established itself already the cutting-out method is the only one that can be followed. Nothing may be expected from the application of poisonous washes.



PARASITES OF THE AMERICAN PLUM BORER.

a, *Idecthis* sp., a common parasite of the plum borer; upper figure, male; lower figure, female; considerably enlarged; *b*, hairworm reared from larva of the plum borer in 1912 at French Creek, W. Va., much enlarged; *c*, cocoon of the parasite *Idecthis* sp. within the cocoon of its host, much enlarged. (Original.)

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BULLETIN No. 262

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.



Washington, D. C.



July 19, 1915.

THE PARANDRA BORER AS AN ORCHARD ENEMY.

By FRED E. BROOKS,

Entomological Assistant, Deciduous-Fruit Insect Investigations.

INTRODUCTION.

During the past few years the larva of a medium-sized brown beetle, *Parandra brunnea* Fab., has attracted considerable attention as an enemy of trees of several widely separated species and of chestnut telephone and telegraph poles. The characteristic injury of the insect to trees is in the form of a multitude of tortuous larval galleries extending through a more or less restricted portion of the trunk or larger branches. The most destructive attacks usually occur in the trunk within a few feet from the ground, the work of the borers being followed quickly by the decay of the affected wood and frequently by the breaking down of the tree (Pl. I, fig. *a*) at the point of greatest injury. (Pl. I, fig. *b*.)

Cultivated fruit trees are often injured by this borer, old apple, pear, and cherry trees being especially liable to attack. Hollow bases and decaying areas and cavities in the trunk and the consequent breaking and falling of weakened trees under the pressure of wind and snow are conditions quite commonly due in a large measure to the work of this insect. Injury is especially noticeable to trees growing in sunny, exposed positions, and the insect seems to be rather more abundant about villages and cities than in country districts, although both the larvæ and adults are found in many dissimilar locations and under a variety of conditions.

Tree surgeons and other persons who attempt to save and rejuvenate fruit trees suffering from diseased and decaying trunks quite often encounter the *Parandra* borer and its work. In cleaning out

NOTE.—This bulletin describes the *Parandra* borer as an enemy of fruit trees, gives its history and distribution, and suggests methods of combating it. It will be of interest throughout the greater portion of the United States.

NOTE.—In Mr. Snyder's interesting article on this species as an enemy to chestnut telephone and telegraph poles (Bul. 91, Pt. I, Bur. Ent., U. S. Dept. Agr., 1910), the beetles are illustrated in Plate I, figure 1, and the male is shown as the larger of the two sexes. Mr. Snyder has discovered that this is an error and wishes us to add that the female is almost always larger, or at least as large as the male.

old cavities in the trunk or larger branches for the purpose of filling with some cement-like material, a practice which is growing in favor, the presence of this borer often forces the operator, in removing all unsound wood, to cut much deeper into the tree than would otherwise be necessary.

While trees of medium age are sometimes attacked, and old trees that have been somewhat neglected suffer most, the borers have also been reported as occurring in nursery stock. Many old orchards that have passed their prime, but are still capable of producing good and profitable crops of fruit, are hastened to their end by this insect.

In two or three specific instances the *Parandra* borer has been recorded as being injurious to fruit trees, and many cases have been reported of the collection of the parent beetle on or about orchard trees. It appears, however, that no recommendations as to remedial measures have been made, and it would seem that further information regarding the insect and its habits and possible methods of reducing or preventing its attacks should be available to fruit growers and owners of fruit-producing trees. For the foregoing reasons this brief account of the species is presented.

HISTORY AND DISTRIBUTION.

The *Parandra* borer has been referred to by previous writers as the "ash root-borer," "chestnut telephone-pole borer," and "heartwood borer." These names, while significant with regard to the habits of the insect, are regarded by the writer as being too restrictive in their meaning to be appropriate as common names, since the borer does not confine its attacks to ash roots, chestnut telephone poles, nor entirely to the heartwood of trees in which it feeds. In fact, it is a very general feeder, attacking the live and dead heartwood and sapwood of a great variety of trees, including pine, black walnut, hickory, willow, beech, chestnut, chinquapin, oak, elm, tulip, apple, pear, plum, wild and cultivated cherry, locust, *Ailanthus*, soft maple, basswood, and black ash.

The *Parandra* borer belongs to the Spondylidæ, a small family closely related to the Cerambycidæ which includes many of the wood-boring larvæ. The species was first described by Fabricius,¹ in the year 1798, and given the technical name which it still bears. In the year 1861 Dr. George H. Horn² made the following record: "The larva of this insect may be seen in almost every locality in which decaying wood may be found. It appears to prefer beechwood, at least I have always found greater numbers in that particular kind of wood." In 1880 the American Entomologist for the month of August acknowledged the receipt by Dr. C. V. Riley of larvæ of this

¹ Fabricius, J. C. *Supplementum Entomologiæ Systematicæ*, p. 49. Hafniæ, 1798. *Tenebrio brunneus*.

² Horn, G. H. Observations on the habits of some coleopterous larvæ and pupæ. In *Proc. Ent. Soc. Phila.*, v. 1, p. 43-44, Sept., 1861; p. 43, *Parandra brunnea* (Fabr.).

species, taken from black ash by Mr. Shelby Reed, Scottsville, N. Y. Various other writers give brief notes on the larvæ and adults as occurring in and about different species of forest trees, but it was not until the year 1890 that a note was published by Dr. F. H. Chittenden¹ of the Bureau of Entomology, associating the species with a cultivated fruit tree. In this note the author states: "found under the bark of domestic cherry; are very common." Mr. Thos. E. Snyder,² in 1910, writes that it has been determined that this beetle damages many species of living forest, fruit, and shade trees. In 1911, Mr. Charles A. Hart³ published an account of this species in which he described the damage done to apple and other trees.

The insect has been found in Ontario, Canada, and in the States of Connecticut, New York, New Jersey, Pennsylvania, Illinois, Minnesota, Maryland, Virginia, West Virginia, Arkansas, Texas, Arizona, and California, and in the District of Columbia. There is little doubt that it may be found over the greater part of temperate North America.

CHARACTER OF INJURY.

The Parandra borer is one of several species of borers from which trees are in very little danger of injury so long as they are kept in sound and vigorous condition. The borers of the present species enter the wood from dead or decaying places on the surface (Pl. II, figs. *a*, *b*) and are probably never found in trees whose trunks and larger branches are entirely covered with healthy bark. Any accident or condition that will produce dead or decaying surface areas, especially about the base of the trunk, may result in a severe infestation by this borer, and, ultimately, in the loss of the tree. (Pl. I, fig. *a*.) Bruises on the trunk made by singletrees or farm tools; cavities resulting from improper pruning; areas killed by winter injury, sun scald, fire blight, collar rot, flatheaded borers (*Chrysobothris femorata* Fab.) and roundheaded borers (*Saperda candida* Fab.) are some of the primary injuries that may result in attacks by the Parandra borer.

When a tree is first attacked the beetles insert their eggs into the surface wood of the dead spots, usually after more or less decay has progressed, and the larvæ or borers extend their burrows throughout the adjacent heartwood and occasionally into the surrounding live sapwood. The borers mine throughout the wood for a period of probably three years, extending their galleries upward more frequently than downward, and finally transform to beetles within the

¹ Packard, A. S. Fifth Report of the U. S. Entomological Commission. Washington, 1890. P. 223. "*Parandra brunnea* Fabr. Under bark. (Chittenden.)"; p. 530, "Found under bark of domestic cherry, are very common."

² Snyder, T. E. Damage to chestnut telephone and telegraph poles by wood-boring insects. U. S. Dept. Agr., Bur. Ent., Bul. 94, Pl. I, p. 6, Dec. 31, 1910.

³ Hart, C. A. The heart-wood borer (*Parandra brunnea* Fabr.). In 26th Rpt. Ill. State Ent., p. 68-73, figs. 5, 1911.

wood. These beetles work their way out through the larval galleries or gnaw through the dead wood to the surface and escape. They return frequently to the dead wood, however, and spend much time hiding in secluded spaces, such as old galleries, within the injured tree. Eggs are now inserted into the wood that forms the walls of the old burrows (Pl. III, figs. *a*, *b*), and the borers of the new brood penetrate still farther into the wood. Other insects and fungi soon appear to accelerate decay, and within a few years that particular part of the tree will consist merely of a thin shell of sound wood surrounding a decomposed heart. A tree so affected may continue to live but will be in danger of falling under a load of fruit or during a storm at any time. The period of usefulness and the lives of many old trees too often terminate in this way.

The work of the *Parandra* borer is sometimes confused with that of the roundheaded apple-tree borer, but a little knowledge of the habits of the two species will enable anyone to distinguish quite readily between them. The two borers bear a general superficial resemblance to each other, but the differences in their methods of attacking trees are distinct. The *Parandra* borer enters at a dead spot or cavity and throws no castings to the surface, whereas the roundheaded apple-tree borer enters living wood and freely extrudes reddish-yellow castings, which form in small heaps at the base of the infested tree. The different positions habitually occupied in the tree by the two borers will serve as a better means of identification than any characters possessed by either while in the larval stage. The *Parandra* borer is slightly more slender and has three pairs of small but rather distinct thoracic legs, while the roundheaded apple-tree borer is legless. The adults of the two species are totally unlike in appearance.

LIFE HISTORY.

The adult *Parandra* borer (Pl. IV, fig. *a*) is a somewhat flattened, glossy, chestnut-brown beetle which is rather variable in size but averages slightly less than three-fourths of an inch in length. The beetles appear on the wing in July and August, the time depending considerably on the latitude. At French Creek, W. Va., the writer found that pupation took place during the last days of June and first days of July in the years 1913 and 1914, and that the adult stage was reached before the 1st of August by each of about 50 individuals kept under observation during that period. The adults remain in the pupal chamber for a week or 10 days and may then continue to stay within the decaying wood of the host tree for a further period before taking flight.

Egg laying begins soon after the beetles quit the pupal chamber. In placing her eggs the female makes small punctures in the wood, probably by the use of both her mandibles and ovipositor. These



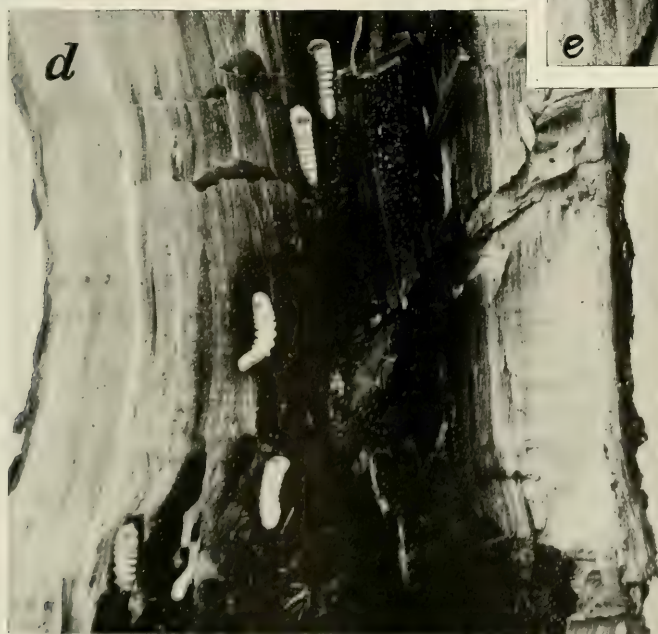
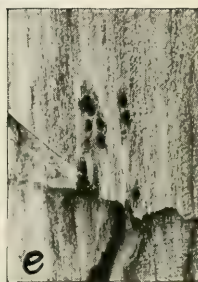
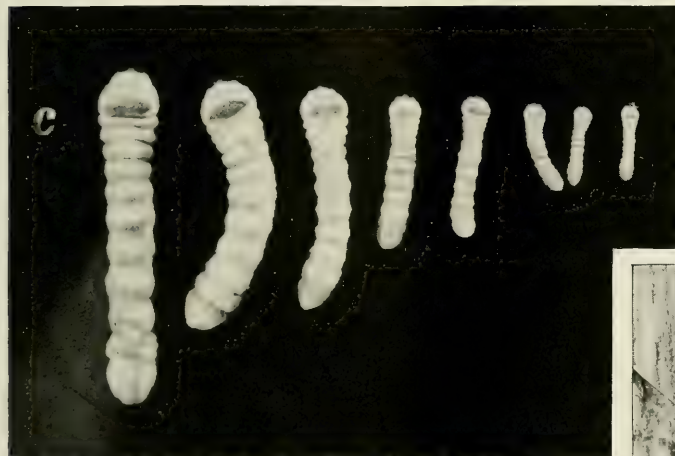
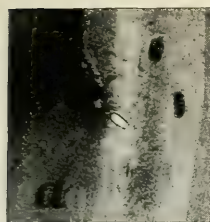
WORK OF THE PARANDRA BORER (*PARANDRA BRUNNEA*).

FIG. a.—Old apple tree broken in storm as a result of injury to the heart by Parandra borers.
FIG. b.—Apple tree with heartwood and sapwood honeycombed by Parandra borers.
(Original.)



ORCHARD CONDITIONS FAVORING THE PARANDRA BORER AND REMEDY.

FIG. *a*.—Section of apple trunk showing favorite place of entrance for Parandra borers. FIG. *b*.—Cavity in trunk of apple tree, formed by the decaying of a dead limb; suitable place for Parandra beetles to deposit eggs. FIG. *c*.—Cavity shown in *b* cleaned out preparatory to filling with cement. (Original.)



STAGES OF THE PARANDRA BORER.

FIG. a.—Egg of the Parandra borer in natural position. Natural size. FIG. b.—Eggs of Parandra borer in natural position in the wood of apple. Much enlarged. FIG. c.—Parandra borers; variety of sizes to be found in an infested tree at any one time. Natural size. FIG. d.—Parandra borers working into heart of apple tree from old wounds made by the roundheaded apple-tree borer, *Saperda candida*. FIG. e.—Group of galleries made by young Parandra borers



a



b



c

STAGES OF THE PARANDRA BORER AND ITS PARASITE.

FIG. *a*.—Adults of the Parandra borer. Much enlarged. FIG. *b*.—Pupæ of *Parandra brunnea* in natural position in wood of apple tree. Natural size. FIG. *c*.—Larva and cocoons of *Odontomerus mellipes*, a parasite of the Parandra borer. Natural size. (Original.)

punctures are about 2 mm. deep by 1-2 mm. wide, and a single egg is placed in each. (Pl. III, fig. *a*.) After the egg is inserted the mouth of the puncture is closed with fine particles of wood. Eggs are deposited in this manner in groups of a dozen or less, placed close together, in either the solid or somewhat decayed wood which forms the walls of larval galleries or other openings in the tree where the beetles can enter. When trees are first attacked the eggs are probably inserted from the surface into the wood of dead areas.

The egg (Pl. III, fig. *b*) is 1.5 mm. long by 0.5 mm. wide, oblong-ovate, and creamy white. The surface is slightly granular. Eggs hatch in two or three weeks, the time not having been definitely determined.

As soon as the larva or borer (Pl. III, fig. *c*) hatches, it begins to feed away from the original position occupied by the egg and extends its gallery in a zigzag course through the wood (Pl. III, fig. *e*). With the exception of the head, which is black, the borer is yellowish white, but the body contents when feeding in dark-colored wood give it a darker appearance. When full grown the larva attains a length of about 1½ inches. It grows slowly and probably remains in the tree for at least three years before changing to the beetle, although this point in the insect's life history has never been fully determined.

The galleries are packed throughout their length with dustlike particles of wood that have passed through the digestive canal of the borer. These galleries wind about in every direction and are usually so numerous as to honeycomb the wood of the affected part of the tree. (Pl. I, fig. *d*.) A single burrow may be several feet in length, but its course is so tortuous that it seldom extends at any point more than a foot away from the place where the egg was deposited. The usual general course is more or less directly into sound wood from a place that is beginning to decay. This results in a rapid enlargement of the area of decay and in the continuous extension of the infested area with the appearance of each successive generation of borers. In many infested trees examined by the writer the Parandra borer was found to have been the first agency to open the way for the spread of decay into heartwood. Other insects follow but less frequently precede them in their attacks on the heartwood of fruit trees.

When the larva is ready to pupate it excavates a cell at the terminus of its burrow in the heartwood large enough to accommodate its body. Within this cell it transforms to the pupal stage (Pl. IV, fig. *b*). The burrow is packed for a short distance next to the cell with coarse, stringlike fragments of wood. This excelsior-like material forms the bed on which the pupa reposes and is evidently provided to insure the drainage of any moisture that might otherwise

collect about the insect during the inactive period of pupation. The pupal stage is from 10 days to 2 weeks in duration.

As has been stated (p. 4) the adults appear in July and August. The writer's observations indicate that the beetles are rather short lived, although Snyder ¹ believes that oviposition may continue from August to October, and Hart ² mentions a specimen collected in Illinois on September 25. The beetles are somewhat sluggish and fly at twilight, perhaps extending their activities throughout the night.

NATURAL ENEMIES.

In the year 1880 Riley ³ mentioned an ichneumon fly belonging to the genus *Pimpla* as parasitic upon the borers of this species. The writer has found the hymenopterous parasite, *Odontomerus mellipes* Say⁴ (Pl. IV, fig. c), attacking the *Parandra* borer in West Virginia. This latter parasite destroys the borer and then constructs an elongate cocoon of white silk within the burrow of the host, in which it changes to the adult form.

The Biological Survey has found this beetle in the stomach of the olive-sided flycatcher (*Nuttallornis borealis*).

REMEDIAL MEASURES.

The first and most important consideration relative to preventing injury to trees by the *Parandra* borer is the keeping of the trees in such a condition of soundness that the beetles will not deposit eggs in them. As has been pointed out (p. 3), the entrance of the borer into the tree is first made at some point where dead wood is exposed by the removal or decay of bark as a result of some mechanical injury or disease. If exposed dead surfaces can be prevented, the danger of attacks from this borer will be eliminated. Injury to the trunks or larger branches of fruit trees, affording favorable places for borer attack, result from a variety of causes, some of which at least are easily preventable. The practice which is not uncommon of leaving stubs 6 inches or more in length in pruning out large branches is quite likely to result ultimately in injury from this insect. The stubs left are practically sure to die back to the trunk and form a decayed spot or cavity that is exactly to the liking of the beetle as a place in which to oviposit. (Pl. II, figs. a, b.) Instead of leaving such stubs when removing large branches, the cut should be made near to the trunk where the natural swell at the base of the branch will insure healing to be most rapid. The cut surface should then be covered with a heavy coat of white lead or some similar paint.

¹ Snyder, T. E. Damage to chestnut telephone and telegraph poles by wood-boring insects. U. S. Dept. Agr., Bur. Ent. Bul. 94, Pt. I, p. 3, Dec. 31, 1910.

² Hart, C. A. The heartwood borer (*Parandra brunnea* Fabr.) In 26th Rpt. Ill. State Ent., p. 72, 1911.

³ Riley, C. V. Ash-root borer: Supposed eggs of *Odontota*. In Amer. Ent., v. 3 (new ser., v. 1), no. 8, p. 202, August, 1880.

⁴ Specimens of this parasite were very kindly determined by Mr. J. C. Crawford, of the U. S. National Museum.

Another common place of entrance for the Parandra borer is near the surface of the ground where injury has been done some time previous by the common roundheaded apple-tree borer.¹ (Pl. III, fig. d.) Such injuries by roundheaded borers often persist as unhealed wounds and are always a source of danger to the tree. If the roundheaded borers are found and removed while they are yet small, the wounds made by them will heal quickly and no danger from attack by Parandra borers will follow. Injuries to the trunks of trees by tools in the hands of careless workmen are possible places for future attacks by Parandra borers and should, of course, be avoided wherever possible. Where such injuries occur they should be cleaned of torn and splintered bark and wood and the surface thoroughly painted.

Winter injuries and diseases attacking the trunk are less easily preventable, but where these are present Parandra borers may be kept out at least temporarily by a liberal use of paint applied to the dead surfaces. Paints so used should be renewed as often as once a year, and the applications may well be made in the spring or early summer.

Whenever borers of this species gain entrance to a tree there is only one practicable way of removing them, and that is to gouge or chisel out all the wood through which their burrows extend. (Pl. II, fig. c.) The cavity should then be properly cleaned and disinfected and filled with cement. Wherever the borers are present at all they are likely to occur in considerable numbers, and it is their habit in feeding to scatter about through the wood so much that little can be accomplished by attempting to remove them with a knife and wire, as is often done with some other species of fruit-tree borers.

In chiseling out the borers preparatory to using cement, all the punctured wood and all the wood soaked with water or affected by decay or disease should be removed. The interior of the cavity should then be sterilized by applying creosote with a brush, after which it should be painted with a heavy coat of coal tar. The cavity should then be filled compactly with a mortar made of one part of a good grade of Portland cement and three parts of clean, sharp sand.²

Trees treated thoroughly in this manner will be practically safe against Parandra borers until new places of attack are formed. However, it is less expensive and more satisfactory in every way to keep trees so far as possible in such a condition of soundness that the borers will find no place to enter.

¹ *Saperda candida*. It is interesting in this connection to note that Dr. F. H. Chittenden, of the U. S. Department of Agriculture, found Parandra borers working on a linden tree on the grounds of the U. S. Department of Agriculture on April 27, 1909, that had apparently entered the tree at a point previously injured by *Saperda vestita*.

² Collins, J. F. Practical tree-surgery. In U. S. Department of Agriculture Yearbook for 1913, p. 163-190, pl. 16-22, 1914. Contains excellent directions for the use of cement in trees.



BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 263



Contribution from Bureau of Entomology, L. O. Howard, Chief.
July 19, 1915.

(PROFESSIONAL PAPER.)

THE CRANBERRY ROOTWORM.¹

By H. B. SCAMMELL, *Entomological Assistant, Deciduous Fruit Insect Investigations.*

INTRODUCTION.²

The investigation of cranberry insects in New Jersey has included the biological study of a beetle, well known to collectors for more than a century, but unrecorded, until recently, as a pest to the cranberry. Attention was first called to it on the cranberry bogs by Mr. T. B. Gaskill, of New Egypt, N. J., who reported injury in a bog in his vicinity and sent specimens of larvæ, pupæ, and beetles to the Bureau of Entomology for determination. Adult specimens, submitted to Mr. E. A. Schwarz, were determined as *Rhabdopterus picipes* Oliv., of the family Chrysomelidæ.

Mr. A. L. Quaintance (1912),³ of the Bureau of Entomology, after making a visit to the infested bog in June of 1912, presented his observations on the extent and character of the injury and the feeding and probable egg-laying habits of the beetle before the Entomological Society of Washington. These notes were the first published records pertaining to the economic importance of this insect.

Rhabdopterus picipes was first described by Olivier (1808) from the collection of Bosc in the Jardin des Plantes, Paris, being placed by him in the genus *Colaspis*. It was later described by Say (1824) under the name *Colaspis pretexta*. Le Conte, when he edited the writings of Say (1859), made note that *Colaspis pretexta* Say is *Colaspis picipes* Oliv. The genus *Rhabdopterus* was erected by Lefevre in 1885, and a few years later Horn (1892) transferred *picipes* from *Colaspis* to *Rhabdopterus*.

Later writers have made mention of the food plants of the beetle, but only one larval host is known. With the finding of the larvæ on cranberry roots and the dying of the vines in infested areas it was deemed advisable to devote special attention to the habits and

¹ *Rhabdopterus picipes* Oliv.; order Coleoptera, family Chrysomelidæ.

² The illustrations used in this paper are from photographs by Messrs. H. K. Plank and J. H. Paine, of the Bureau of Entomology. The author is also pleased to acknowledge the assistance of Mr. Plank in carrying on life-history studies of the cranberry rootworm.

³ Bibliographic citations in parentheses refer to "Literature cited," p. 8.

distribution of the insect with a view to devising means of control, (1) by spraying, (2) by the use of water for flooding operations, and (3) by cultural treatment of the bogs. Observations continued through a period of two years indicate that at the present time the pest is not one of prime importance on cranberry bogs and that its ravages are not to be compared in severity with those of the cranberry girdler (*Crambus hortuellus* Hübn.) to which insect probably the injury produced by the rootworm has heretofore been attributed.

DISTRIBUTION.

The cranberry rootworm is widely disseminated throughout the United States and is also reported from Canada. Blatchley (1910) reports it in Indiana and further states that it occurs from Massachusetts to Dakota and south to North Carolina. In the collection of the Philadelphia Academy of Natural Sciences specimens are exhibited from Utah, Nebraska, Illinois, "Dakota," southwestern Texas, Florida, Delaware, Pennsylvania, New Jersey, and Canada. Smith (1909) lists it from New Jersey south of the Piedmont Plain. The present investigation has led to its capture on one or more cranberry bogs at or near the following places in New Jersey: Pemberton, New Lisbon, Whitesbog, New Egypt, Cookstown, Chatsworth, Pasadena, Medford, and Brookland.

FOOD PLANTS.

Few plants are recorded as hosts of the beetle. Say states that it is common on the myrtle, while Blanchard found it abundant on basswood. In Indiana it is reported on wild grape, and Smith lists it in New Jersey on myrtle, grape, and basswood. More recent observations have shown that the beetle is a feeder on foliage and fruit of the cranberry, and the writer has taken it on blueberry and inkberry by jarring. The larvæ are abundant on the roots of cranberry.

CHARACTER AND EXTENT OF INJURY.

The chief injury to the cranberry is caused by the feeding of the larvæ on the roots and runners (Pl. I, fig. 2), where the latter come in contact with the ground. As a rule only the bark is eaten from the large and secondary roots, the wood occasionally being attacked, while the fibrous roots (Pl. I, fig. 1), which are so numerous as to form a dense mat an inch or more in thickness, are completely devoured. The character of the rootworm injury is such that one can distinguish between it and the injury produced by the cranberry girdler. The larvæ of the latter insect prefer the runners and crowns of the plants and not only feed on the bark but devour the wood, often eating completely through a runner. In a general way it may be said that the rootworm feeds in the soil, while the girdler feeds on the surface, concealed in the trash which lies on the ground.

The vines which suffer the most are those growing on sandy land or what are usually termed "savannas." Larvæ have been found in

several instances in peat bottoms, where the roots of the vines may travel a foot in depth, but in these instances the dying of the vines could usually be traced to the feeding of the cranberry girdler.

When the root feeding is severe the vines show signs of weakening in the early fall. The leaves dry out, turn red or brown, and before growth starts the following season most of them will have shattered to the ground, leaving the dead uprights and runners bare of green foliage. Small areas are thus killed out, almost invariably at the margins of the bogs or on relatively high and sandy areas in the interior of the bogs. (Pl. II, fig. 1.) The mud and peat bottoms rarely suffer from rootworm attacks, presumably because the root system of the cranberry is so much thriftier and more extensive in these soils than in sand and possibly because the beetles seek sandy soil in which to deposit their eggs.

The injury produced by the feeding of the beetles on the foliage and berries is so slight as to be almost negligible. This habit, however, affords a means of control, namely, of poisoning their food by the use of insecticides.

DESCRIPTION OF STAGES.

THE ADULT.

The adult (Pl. II, fig. 3) is a shining brown beetle measuring less than one-fourth of an inch in length. The following description of the adult is taken from Blatchley; those of the other stages are by the author.

Oblong, oval, convex. Brown, bronzed, strongly shining, the elytral margin often greenish-bronzed; antennae and legs reddish-yellow, the outer joints of former often dusky; under surface of body greenish, abdomen brown, its tip paler. Head coarsely and sparsely punctate, clypeus more closely punctate. Thorax nearly twice as wide as long, narrowed in front, sides strongly curved, hind angles prominent; disk rather sparsely and finely punctate, elytra coarsely but not closely punctate, the punctures irregular on the disk, a line representing the third interval smooth. Length 4-5 mm.

THE EGG.

The eggs (Pl. II, fig. 2) of the cranberry rootworm measure 0.67 mm. in length by 0.30 mm. in width. In shape they are regularly elongate, elliptical. When first deposited they are a dirty white in color, later becoming uniformly yellow. The shell is smooth and glistening, and sufficiently transparent to reveal the larval outline before hatching.

THE LARVA.

The full grown larva (Pl. II, fig. 5) measures from 7-9 mm. Normally it lies in a curved position so that its full length is seldom revealed. Its color is whitish with head light brown and thoracic shield of very pale yellowish brown. Tips of mandibles black, shading off to light brown at the base. Labrum and clypeus brown. A row of brownish spines, the ambulatory setae, on each ventral abdominal segment projects obliquely backward. Setae long. Legs slender and small.

THE PUPA.

The pupa (Pl. II, fig. 4) is slightly shorter than the extended larva, whitish in color. Spines on the head and thorax are longer and stouter than those in the larval

stage. The middle and posterior femora are each provided with one curved spine and two straight, more slender spines; two flattened hooklike spines, curving outward, are found at the posterior end of the abdomen.

LIFE HISTORY AND HABITS.

ADULT STAGE.

Emergence of the beetles from the soil begins about mid-June, the maximum number emerging in breeding cages June 28. This date will vary, however, depending upon the time of drawing the winter flood from the bog; as early as June 6 beetles in the process of hardening were taken from the soil whereas the latest capture of the season was made October 20. They are easily captured by sweeping the bog with a net and with more difficulty by searching in the fallen leaves and refuse which often form a layer of trash an inch or more in depth under the vines. The beetles go into the trash so that they may deposit their eggs in the soil, and to find them one must carefully turn over the litter. Some are on the vines, feeding usually on the new growth of foliage, which they attack from the outer margin. Others may be found on the small berries, gouging shallow furrows around the fruit. When disturbed they fly short distances, seldom more than three or four feet. A few cage experiments showed that the females are longer lived than the males, one female remaining alive 56 days.

EGG STAGE.

Eggs have been found in a cranberry bog lying in a mass just beneath the surface of the ground. In rearing cages they are most frequently deposited in masses but occasionally are found singly. The highest number found in one mass and known to have been laid by one female was 53 eggs. The average number of eggs per mass was 14. Caged beetles sometimes oviposited on the sides of the cage or on fallen leaves, but most frequently the eggs were inserted about an eighth of an inch in the soil. In a previous report on the cranberry rootworm the writer (1914) gave the length of the egg stage as 11 days. Further data show that this period varies from 6 to 11 days, averaging 8 days.

LARVAL STAGE.

The small larvæ find their food in the first inch or two inches of roots and soil and, owing to the fact that the fibrous roots are so abundant, it is presumed that the larvæ travel little in search of food. Larvæ may be found feeding at all times during the summer and until quite late in the fall, at which time some of them go deeper into the ground. November 17, Mr. H. K. Plank, of the Bureau of Entomology, found larvæ in a peat soil at depths ranging from an inch to 1 foot. December 1 the larvæ were found in the first 2 inches of a rather dry, sandy soil. When feeding ceases a round cell is formed in the soil within which the larva hibernates until spring. If the bog is flooded during the winter the larvæ remain dormant, at least until the winter

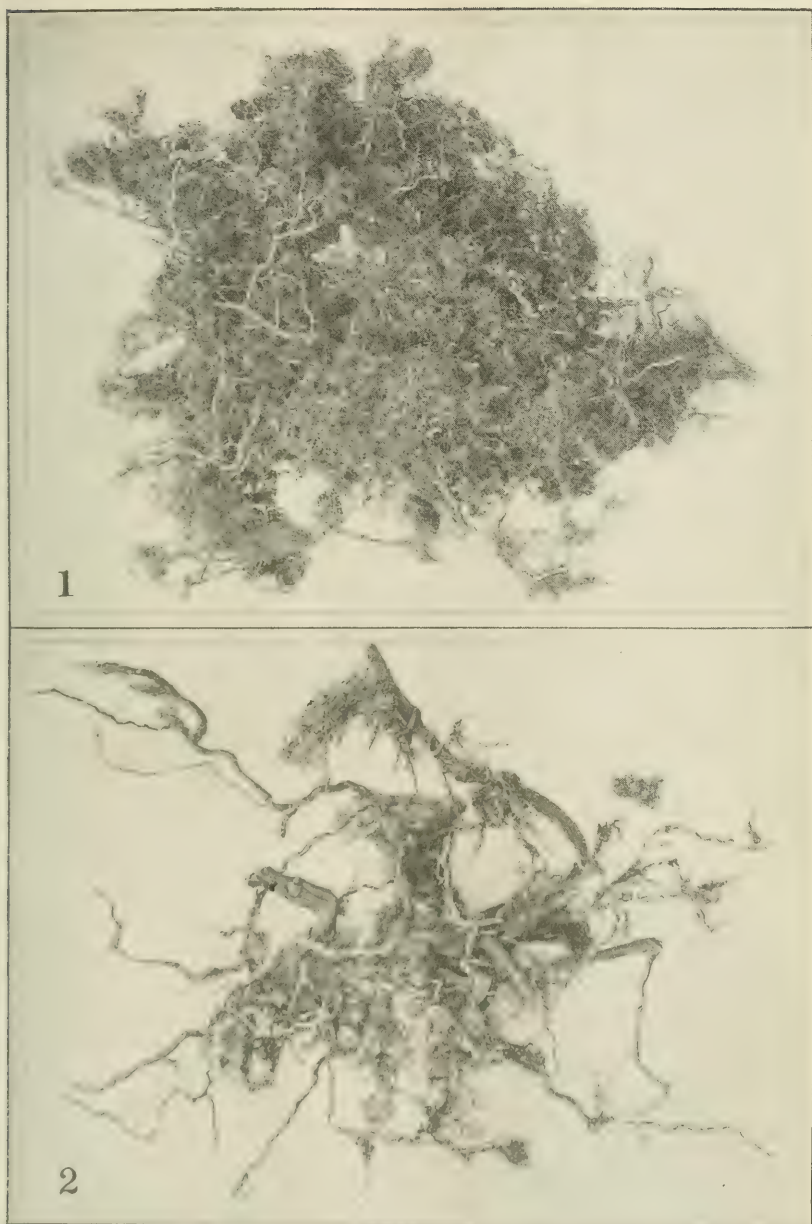


FIG. 1.—NORMAL ROOT SYSTEM OF THE CRANBERRY GROWN ON SAVANNA BOTTOM.
FIG. 2.—INJURY TO CRANBERRY ROOTS BY THE LARVÆ OF THE CRANBERRY ROOT-
WORM (*RHABDOPTERUS PICIPES*). (ORIGINAL.)

WORK OF THE CRANBERRY ROOTWORM.

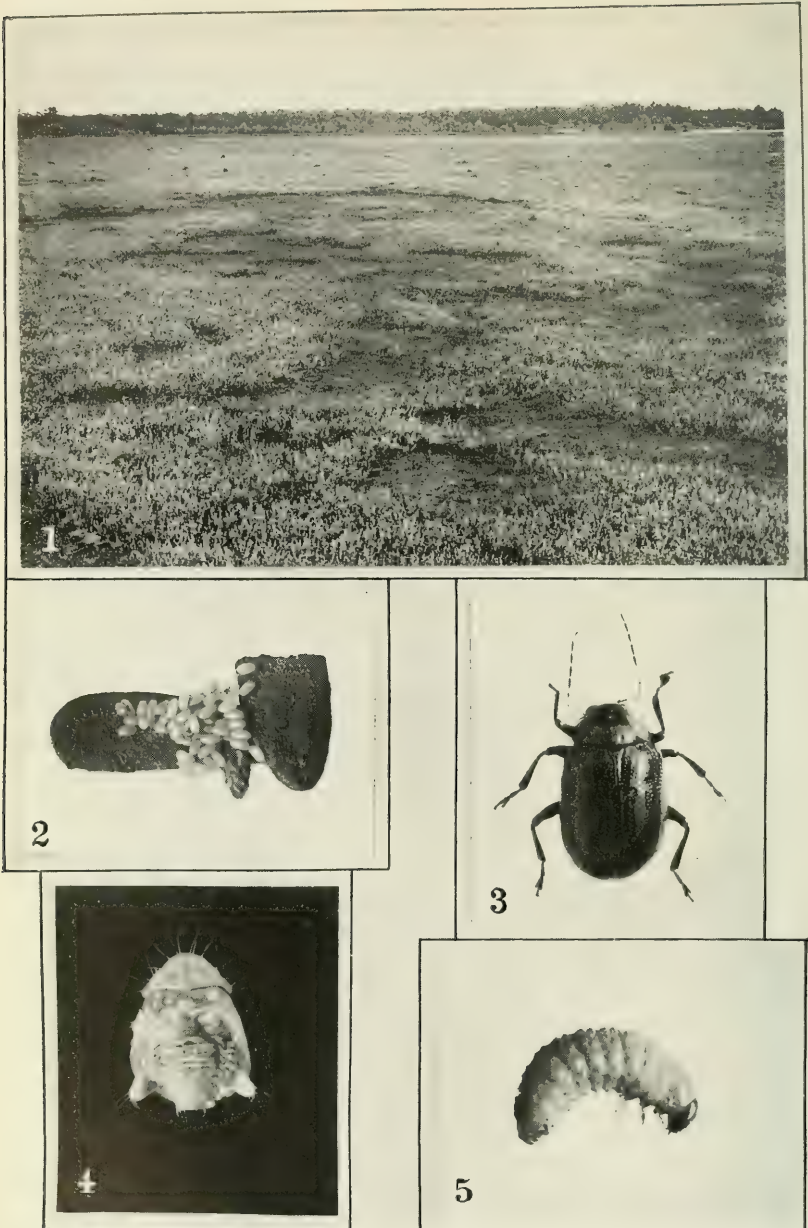


FIG. 1.—CRANBERRY BOG, SHOWING DEAD AREAS CAUSED BY THE LARVAL FEEDING OF THE CRANBERRY ROOTWORM (*RHABDOPTERUS PICIPES*). FIG. 2.—EGG MASS. FIG. 3.—ADULT. FIG. 4.—PUPA. FIG. 5.—LARVA. (ORIGINAL.)

THE CRANBERRY ROOTWORM AND ITS INJURIES.

flood is drawn in the spring. Soon after the water is drawn the larvæ commence to feed again, which may be noted by the fresh barking of the roots. Before commencing to pupate the larvæ move closer to the surface of the bog, the majority being found in the first inch of soil. Some idea of their abundance was obtained by counting the larvæ under plats of soil 10 inches square. Twelve larvæ were obtained in one instance and other counts of 11 and lesser numbers were made where the injury to the vines was quite apparent. From the foregoing it will be seen that the species spends most of its life in the larval stage, or approximately 10 months. Possibly some of the larvæ fail to mature at the expiration of this period and spend another year in the bog before reaching the adult stage.

PUPAL STAGE.

The time when pupation commences varies somewhat with the management of the bog. The earlier the flood is drawn the earlier will be the date of general pupation. In 1913, when the water was drawn April 1, pupæ were in the majority June 6; while in 1914, when the water was drawn May 20, the larvæ outnumbered the pupæ two to one on June 15. Pupation studies were carried on in wooden cages having glass bottoms, which permitted one to observe those larvæ which formed cells against the glass. The average duration of the pupal stage was found to be $14\frac{1}{2}$ days, and from 2 to 3 days were spent by the adult hardening in the cell and reaching the surface.

SUMMARY OF LIFE HISTORY.

Stage.	Period of usual occurrence.	Range in occurrence.	Usual duration.	Range in duration.
			<i>Days.</i>	<i>Days.</i>
Adult.....	June 20-Aug. 1.....	June 6-Oct. 20.....	35	56
Egg.....	July 10-30.....	July 10-Sept. 3.....	8	0-11
Larva.....	July 16-June 1.....	All seasons (months).....	$10\frac{1}{2}$	-----
Pupa.....	June 10-30.....	May 25-July 9.....	$14\frac{1}{2}$	13-17

RECOMMENDATIONS FOR CONTROL.

Some way in which to control an insect infestation by the use of water usually first suggests itself to one connected with the cranberry industry. The particular bog, however, upon which most of the observations were made has an insufficient water supply limited to a winter flooding with no available water for reflooding. Late holding of the water—that is, until May 20—had no effect in reducing the infestation. The larvæ were in as good condition after this treatment as when, the year previous, the water was drawn April 1. Laboratory experiments have shown that the larvæ can live submerged in clean water for as long as 41 days, while pupæ have not survived more than 9 days. Examination of a bog which had been reflooded for a period of 4 days in the latter part of May disclosed many live larvæ but no

dead ones. Another bog, in which the insects were found to have reached the pupal stage, was reflowed May 28 and 29 for a period of 27½ hours. Soon after the water was drawn from this bog a second investigation was made which revealed no dead pupæ and 49 live pupæ. Reflowing the bog when the beetles have emerged from the ground and before egg laying has commenced would undoubtedly carry some of the beetles ashore where they could be killed with kerosene, but this operation would have to come at a time when the young berries are forming, and the use of water at that time is apt to be disastrous to the setting of the crop.

Carbon bisulphid was given a trial to determine its effect on larvæ and pupæ in the soil. Used in holes at varying strengths of the liquid and varying depths and distances apart, negative results were obtained in each plat. In plat 1 the holes were made a foot apart and 4 inches deep and into each was poured one-half fluid ounce of carbon bisulphid. The liquid nearly filled each hole and all holes were covered with soil and tamped with the foot. Larvæ found within 2 inches of some of the holes were unaffected by the gas. The failure of this substance to kill is thought to have been due to the wetness of the bog which prevented the fumes from penetrating the soil. No injury resulted to the vines except where drops of the liquid were spilled on them from above.

Observations of two seasons' spraying on a bog near New Egypt, N. J., have shown that an arsenical, added to the customary Bordeaux and resin-fishoil soap used to control the fungous diseases of the cranberry, is of value in killing the beetles which feed on the foliage. Arsenite of lime at the rate of 1 pound of white arsenic per 200 gallons of Bordeaux mixture per acre was the poison applied by the owner of the bog the first year. Two applications were made, the first beginning July 1 and the second July 14. In 1914 the bog was sprayed more frequently owing to the presence of an infestation of fireworms (*Rhopobota vacciniana* Pack.). The dates of spraying were June 11, June 18, June 30, July 9, and July 20. Arsenite of lime was used in each instance, but beginning with the third application a different method of preparing it was employed, as follows—1 pound of caustic soda was dissolved in 2 quarts of water and while this was dissolving, 2 pounds of white arsenic were added. It is essential in preparing arsenite of soda after this formula that a very good grade of caustic soda be secured, otherwise some of the arsenic may remain uncombined and produce injury to the foliage or fruit. In five minutes the arsenic was completely dissolved, leaving a clear solution if the crystalline variety of arsenic was used, or a silt-colored solution if the amorphous arsenic was employed. The presence of a small amount of lead in the amorphous arsenic seemed to account for the cloudiness of the solution. Mr. F. S. Chambers, of J. J. White (Inc.),

New Lisbon, N. J., was the first to introduce this method of preparing arsenite of soda for use in the spraying of New Jersey cranberry bogs.

In the first two applications arsenic was used at the rate of $1\frac{1}{2}$ pounds per acre, the later applications being increased to 2 pounds per acre. Arsenite of lime, prepared and used as just described, is exceedingly cheap compared to arsenate of lead, but the dangers attendant upon its use by inexperienced help, both to human life and from possible injury to the foliage and fruit, are such that it is preferred to recommend arsenate of lead for general use. The latter insecticide is frequently used on cranberry bogs at the strength of 3 pounds of paste arsenate of lead to 50 gallons of water or Bordeaux mixture. If arsenite of lime is used as the insecticide, it is very essential that thorough agitation of the spray material be maintained. Some foliage injury, noted on three different bogs, should probably be attributed mainly to a neglect to keep the mixture agitated at all times when spraying. At the conclusion of the second season's observations no new areas on the sprayed bog were found infested and the number of larvæ throughout the bog had decreased to a marked degree.

Having observed on a number of bogs that the injury by the rootworm almost invariably occurs on sandy land and, further, that the root system of the cranberry on such land is exceedingly shallow as compared with that on peat or muck lands, it is fair to conclude that treatment of the bog by fertilizers to stimulate growth will be of great advantage to the cranberry plant in outgrowing the injury of the larvæ.

The New Jersey Experiment Station has amply demonstrated at Whitesbog, N. J., that weak vines on sandy soil can be made to produce an abundance of vines in one season by the application of the proper mixture of chemical fertilizers. It so happens that this land is infested with rootworms, but the extent of the infestation could not be definitely determined without tearing up the fertilizer plats more than is advisable. Some of the plats are known to be infested, but in spite of the presence of the rootworms the vines have made so much growth in two years that pruning would not be inadvisable.

Sanding infested areas also gives promise of being a satisfactory method of promoting vine growth. Mr. T. B. Gaskill, of New Egypt, N. J., has clearly demonstrated on a small, badly infested area of savanna land that a 1-inch coat of sand will cause the vines to grow vigorously, sending out runners which cover the bare spaces, and to present a marked contrast to unsanded adjacent vines.

SUMMARY.

The cranberry rootworm (*Rhabdopterus picipes* Oliv.) is the larva of a small brown beetle which has recently been found on a number of cranberry bogs in New Jersey.

It is widely distributed throughout the United States, but previous to its discovery on the cranberry it was not regarded as of economic importance.

The number of its known food plants is few.

The chief injury to the cranberry is produced by the feeding of the larvæ on the roots. The beetles feed on the foliage and fruit.

Its injury occurs mainly on sandy land or savannas, where the root system of the vines is not so extensive as on muck or peat bottoms.

The beetles appear in numbers about the end of June, deposit eggs in the soil, and die before fall.

The larvæ feed on the fibrous roots and bark of the larger roots until late fall, when they hibernate in cells formed in the soil.

Some spring feeding of the larvæ occurs.

Pupation commences early in June, the average duration of the stage being $14\frac{1}{2}$ days.

No satisfactory practice in the use of the winter flowage or the spring reflowage to exterminate an infestation of larvæ or pupæ has been developed.

Invigorating the vines by the application of fertilizers or sand promises excellent results.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 264

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.



June 15, 1915.

THE VIOLET ROVE-BEETLE.

By F. H. CHITTENDEN, Sc. D.,

In Charge of Truck Crop¹ and Stored Product Insect Investigations.

INTRODUCTION.

Beginning with the year 1901 a small dark-colored rove-beetle, known to science as *Apocellus sphaericollis* Say, has been reported as an enemy to violets and other succulent ornamental plants in the District of Columbia and from St. Louis, Mo. This insect is a very common one in the United States and is quite generally known as a scavenger, feeding on humus and decaying vegetation and similar matter. That it feeds on violets as well as on a variety of other vegetation is now undoubted. Informants have furnished abundant proof of this in the eaten flowers and leaves, while beetles in confinement in the writer's laboratory were observed by him to attack violets and other plants. Nor does the insect confine itself to plants grown indoors or in gardens, since in its Washington occurrence the violets were grown in hothouses and at St. Louis the various plants affected were growing in the open. There is no doubt, however, that although the habit of the insect of feeding on delicate flowers and leaves is well established it is nevertheless an acquired taste, the insect living normally like others of its kind on old, dead leaves or in soil which has been covered by leaves over winter.

Undoubtedly injury by this species is more extensive than our notes show. This may be ascribed mainly to the resemblance of this insect, to the casual observer at least, to an ant, and to the fact that the beetles swarm in numbers on plants in the manner of ants. The year after the first report of injury by this species so many complaints of injuries by ants in greenhouses were made that the Florists' Exchange² asked the writer for an article bearing upon this subject.

¹A large proportion of the insects which infest the garden also infest greenhouses, as in the present instance. Next to roses, violets are favorite flowers grown in this and some other countries. In Bulletin No. 27, new series, Bureau of Entomology (out of print, but available in libraries), a somewhat comprehensive publication on violet insects was furnished.

²F. H. C. A violet pest. In The Florists' Exchange, v. 36, No. 23, p. 1216, Dec. 6, 1913.

It now seems probable that in some of these cases the rove-beetle might have been the culprit. The complaints cover scatteringly a span of 12 years.

It has been hoped that something more definite than is recorded concerning the life history of the insect could be learned before publication. The notes now presented, however, show conclusively the injurious character of the insect, and the remedies advised and used have proved perfectly successful, showing that it is not by any means a difficult insect with which the gardener or florist has to cope.

DESCRIPTIVE.

The ant which this beetle especially resembles is known as the pavement ant (*Tetramorium caespitum* L.). This ant often occurs in greenhouses, but when the two insects are carefully compared the much larger antennæ, or "feelers," of the beetle will readily be noticed.

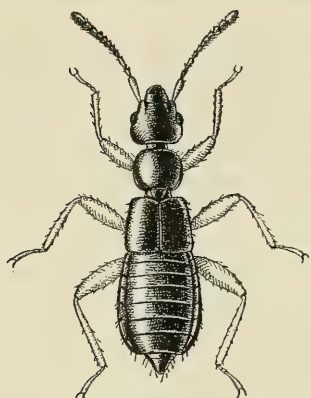


FIG. 1.—The violet rove-beetle (*Apocellus sphaericollis*): Adult. Greatly enlarged. (Original.)

Apocellus sphaericollis belongs to the group Oxytelini of the family Staphylinidæ, and is the sole representative of its genus occurring in the United States. It was originally described by Say in 1834, under the name of *Lathrobium sphaericolle*. The general appearance of the insect is shown in the accompanying illustration (fig. 1). The head is only slightly larger than the thorax, which is somewhat rounded. The elytra or wing covers are very short, as is usual in typical Staphylinidæ. The femora or thighs are larger than those of ants, but this is not noticeable at a distance when the insects are at work. The total length of the insect is about 2.5 millimeters.

October 14, 1901, Mr. L. J. Barber, Wheeler Road, near Congress Heights, Washington, D. C., brought living specimens of this rove-beetle, with report that it was injuring violets grown in hothouses, particularly low-growing forms, but did not attack the high-growing plants. He was positive that the beetles destroyed the flowers by riddling them with holes, and in response to inquiry thought it quite probable that they were introduced in manure that he was using.

Injury was thought, both by Mr. E. A. Schwarz, of the Bureau of Entomology, who furnished the identification of the species, and by the writer, to be due to some other insect, but Mr. Barber stated otherwise.

Two days later he brought specimens of the beetles with single-flowered violets which had not previously been attacked. Some of these already showed injury by the beetles. The chief injury was to the Marie Louise double violets, which grow with the flowers resting on the ground, and to Campbell double flowers, which are on the ground in their early stage but afterwards become erect. It seems that the beetles crawl directly from the ground to the flowers, and this accounts for the single-flowered varieties being free from infestation. No part of the plant other than the flowers was injured or attacked, so far as could be ascertained.

August 14, 1905, Mr. G. Pauls, St. Louis Altenheim, St. Louis, Mo., sent a specimen of this rove-beetle, which he stated was the greatest plant destroyer of the year at the Altenheim. The plants affected included lilies, dahlia, pansy, forget-me-not, and other soft plants, which were destroyed. The beetles were described as occurring everywhere, but preferring a low or mulch soil, especially under fallen leaves. September 9, 1905, he sent additional specimens with a plant of portulaca, which they were attacking. In his pansy beds, which they had completely ruined, the chickweed and yellow wood sorrel were not troubled. Portulaca seemed to be a favorite food.

November 21, 1913, the Florists' Exchange of New York furnished specimens of this insect on violets, requesting the name of the insect and asking what could be done to remedy the evil. Exact locality was not furnished.

REMEDIES.

Acting by the writer's advice, Mr. Barber used decaying leaves, deposited in piles at regular intervals about infested violet plants. This attracted the rove-beetles, after which the leaves were quickly dipped into hot water, which killed the insects, the leaves afterwards being restored as traps.

Four years after the first occurrence of this insect on hothouse violets it had disappeared as a pest, Mr. Barber reporting that he had used spinach, kale, and chickweed as traps, as advised. The same year Mr. Pauls reported that he had been successful in ridding his garden of this pest, at least on three of his pansy beds, by dusting them with tobacco. As a rule he could find no more rove-beetles, although in adjoining beds they were nearly as plentiful as before treatment. This report was received September 20, 1905.

There can be little doubt that injury by this species might be prevented by care in looking over the soil, or the dead leaves used as a mulch in violet or pansy beds, for the presence of the insect. Sterilization of this material before using would result in the destruction of the insect and prevent its introduction into the greenhouse or flower beds.

It might be added that it is fortunate that we can control this insect by comparatively simple means, since it is not desirable to fumigate violets when they are in bloom. Nicotine extracts are practically impossible, because of the more or less permanent odor which would obliterate that of the violets, and it is equally obvious that the use of arsenical sprays would be inadvisable.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 265



Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

December 29, 1916

THE DOCK FALSE-WORM: AN APPLE PEST.

By E. J. NEWCOMER,

Scientific Assistant, Deciduous Fruit Insect investigations.

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INTRODUCTION.

The dock false-worm is the larva of an allantine sawfly (*Ametastegia glabrata* Fallén) which may be called the dock sawfly. It has long been known, both in Europe and America, as an enemy of dock, sorrel, and knotweed, all common and sometimes troublesome plants which are to be found growing in moist places everywhere. Its acquired habit of boring into mature apples on the tree, to hibernate, thereby destroying their market value, brings it into prominence as an economic pest and has been noted by several observers in this country. Fletcher, in 1903 (30, 31)¹ and 1904 (33), reported finding the larva of a sawfly, which proved to be this species, boring into apples in Ontario in rather large numbers, and R. L. Webster (36) mentions the presence of these green worms in apples from New York, in 1908. Prof. A. L. Melander, of the Washington Experiment Station, in a letter to the Bureau of Entomology, under date of November 1, 1912, reports having known of the fruit-burrowing habit of this larva in British Columbia and since 1903 in Washington, particularly at Lynden, Whatcom County, where the injury amounted to about 10 per cent.

¹ Figures in parentheses refer to Bibliography, p. 38-39.

In the fall of 1914 the writer's attention was called to a number of apples which had been perforated in one or more places, the holes being round, about 2 millimeters in diameter, and similar in appearance to those caused by an apple stem or by the apple falling on alfalfa stubble. These holes, however, were evidently the work of an insect. On cutting open these apples, one or more bright-green worms were found in each, in the burrows extending from the entrance holes. These larvæ were not feeding but were lying dormant, as though intending to pass the winter here. They appeared to be the larvæ of a sawfly, and, on looking up the literature, it was found that the larvæ of the dock false-worm were known to bore into apples occasionally. Adults were secured the following spring and definitely determined by Mr. S. A. Rohwer as *Ametastegia glabrata* Fallén. A visit on September 30, 1914, to the orchard from which these apples came, which is situated along the Entiat River, a tributary of the Columbia River in north-central Washington, showed that the injury from these larvæ was of some importance, about 2 per cent of the early apples, Jonathans and King Davids, being injured. This amounted to considerably more than the injury caused by the codling moth, which is as yet uncommon in this valley. Dr. A. L. Quaintance, entomologist in charge of Deciduous Fruit Insect Investigations, suggested that a study of the insect be made, and accordingly a number of infested apples were kept over the winter. Early in the spring the orchard was again visited, and several hundred hibernating larvæ, which had burrowed into the alfalfa stubble on the ground, were collected. With this abundant material a study of the life history and habits of this insect was begun, and the results form the subject of this paper. The writer is indebted to Mr. S. A. Rohwer, of the Bureau of Entomology, for suggestions and information regarding this species, and to Mr. Frank E. Knapp, of Entiat, Wash., for permission to carry on observations and control experiments in his orchard.

HISTORY.

The dock false-worm has been known for more than a hundred years, the adult having been originally described in Sweden by Fallén (1), in 1808, as *Tenthredo glabrata*. It was subsequently described under several names and placed in several genera in Europe, as shown in the synonymy below. The larva appears to have been first recognized by Kaltenbach (6) in Germany in 1859. The adult insect was originally described in America in 1862, by Norton (8), as *Taxonus nigrisoma*, and this name has been generally used in this country, although the name *Strongylogaster abnormis* was also applied to the species by Provancher (22) in 1885. The larva was first noted here by Jack in 1893. In a recent paper by Rohwer (37), it is considered that the European and American species are identical, and therefore,

according to the laws of priority, the specific name *glabrata* Fallén should be used, and the species belongs in the genus *Ametastegia*. The synonymy, as worked out by Rohwer, is given below:

AMETASTEGIA GLABRATA (Fallén).

Tenthredo glabrata Fallén, Svensk. Vet.-Akad. Handl., p. 108, 1808.

Tenthredo (*Allantus*) *agilis* Klug, Magaz. Ges. Naturf. Fr. Berlin, viii, p. 208, 1814.

Tenthredo (*Allantus*) *rufipes* Lepeletier, Monog. Tenthred., p. 81, 1823.

Ametastegia fulvipes A. Costa, Rendic. Acad. Sc. Napoli, xxi, p. 198, 1882.

Taxonus nigrisoma Norton, Proc. Boston Soc. Nat. Hist., ix, p. 119, 1862.

Strongylogaster abnormis Provancher, Addit. Faun. Can. Hym., p. 10, 1885.

DISTRIBUTION.

The dock false-worm is widely distributed in both Europe and America. In Europe it has been found as far north as Lapland, in northern Russia, and as far south as Italy. It is also recorded in the literature from Scotland, Sweden, Russia, northern Germany, southern Bavaria, Holland, and France.

In America the dock false-worm appears to be confined to Canada and the northern part of the United States. Provancher and Fletcher have observed it in Ontario, the latter having found the larvæ burrowing into apples. Norton's description of *Taxonus nigrisoma* is from specimens taken at Dorchester, Mass., and Jack found the larvæ at Jamaica Plain, both just south of Boston. From the other articles which have appeared concerning this species, and from the specimens in the National Museum collection, the following additional localities are taken: Stratford, Conn. (Walden), New York City and Flatbush, L. I. (Dyar), Seacliff, L. I. (Banks), Sherbrooke, Quebec, Harrisburg, Pa. (Myers), Menominee, Mich. (Chittenden and Titus), Ames, Iowa (Webster), and Minnesota (Ashmead collection). In the West the writer has found it very abundant in north-central Washington, at Wenatchee and Entiat, in Chelan County, and Prof. Melander reports it from Lynden, Whatcom County, Wash., from Kittitas County, Wash., and from British Columbia. It is very probable that the species has an almost continuous distribution in America from the Atlantic to the Pacific. It has never been recorded south of 40° north latitude, either in Europe or America, although some of its food plants are found farther south.

It is probable that the dock false-worm is distributed chiefly when in the prepupal or pupal stage in the dry stems of plants, for it is well protected here and during the winter season is to be found in these stems for a period of six months or more. The stems and stalks are very likely to be carried about in hay, packing materials, etc. In the egg and active larval stages the insect is greatly dependent on the fresh leaves of its food plant, and the adults, though active, are not strong flyers; thus it is not possible for the insect to travel far in these stages.

FOOD PLANTS.

The dock false-worm probably confines its feeding almost entirely to plants belonging to the buckwheat family (Polygonaceæ), including the numerous docks and sorrels (*Rumex*), the knotweeds and bindweeds, or wild buckwheat (*Polygonum*), and others.¹ It has been recorded from *Polygonum bistorta* in Scotland, and from *Polygonum* sp., *Persicaria* sp., and *Rumex* sp. in Germany. In America it has been recorded from the common knotweed (*Polygonum lapathifolium* and *P. muhlenbergii*), and from a yellow dock (*Rumex patientia* or *britannicus*). The writer has taken it on *P. lapathifolium*, on bindweed or wild buckwheat (*P. convolvulus*), on sheep sorrel (*Rumex acetosella*), on curly dock (*R. crispus*), bitter dock (*R. obtusifolius*), and willow dock (*R. salicifolius*). It was also

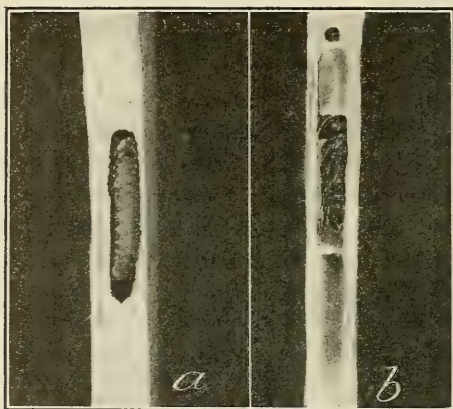
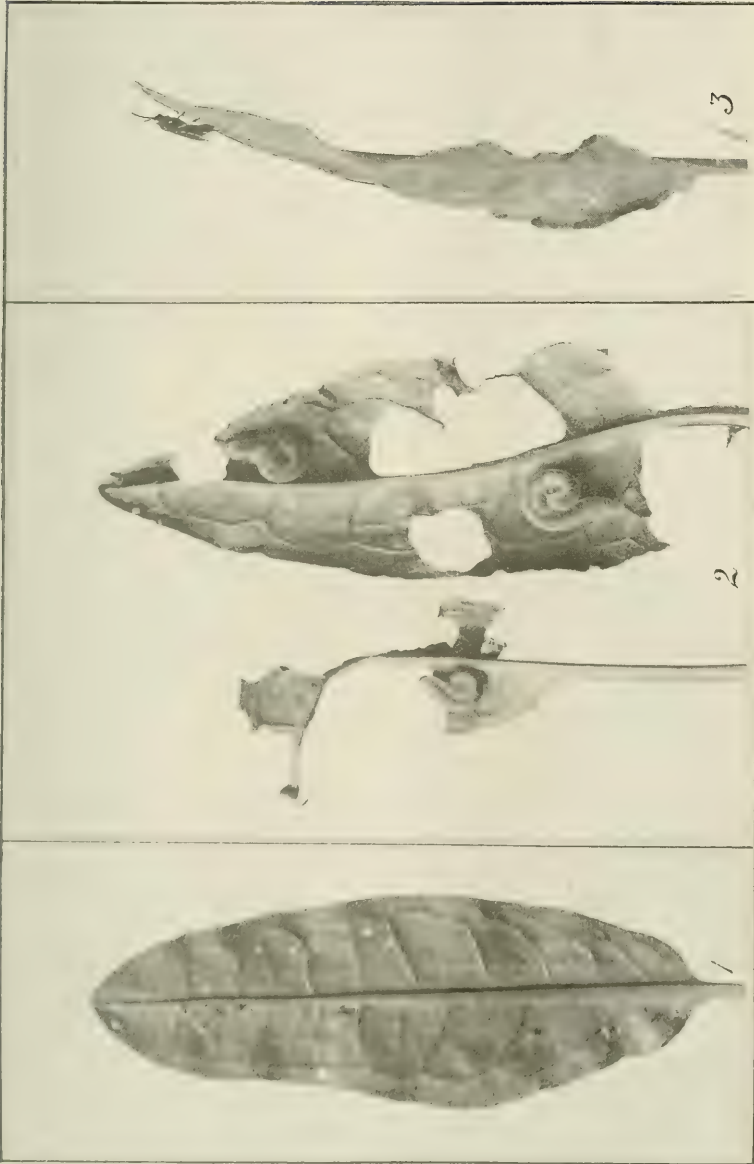


FIG. 1.—The dock false-worm (*Ametastegia glabrata*): a, Larva in hibernation cell in stalk of the dock plant; b, pupa of dock false-worm in larval hibernation cell. Enlarged. (Original.)

found by Chittenden and Titus (34) feeding on the leaves of the sugar beet (*Chenopodiaceæ*), in a field where it had evidently consumed all of the dock and was forced by hunger to feed on this plant. The common cultivated buckwheat and rhubarb belong to the Polygonaceæ and may very well be food plants of this insect, though it has never been recorded from them and the writer has not had the opportunity of testing them.¹

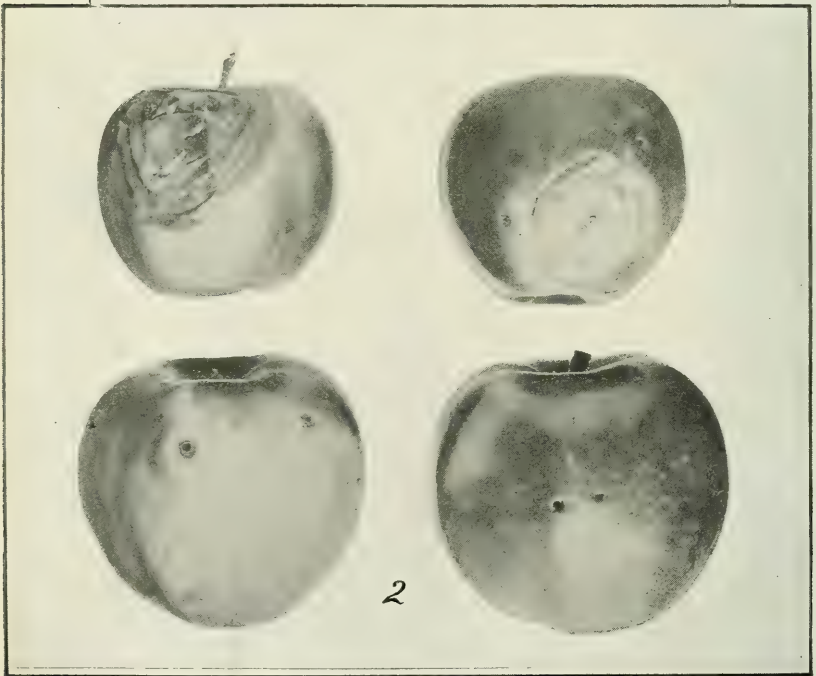
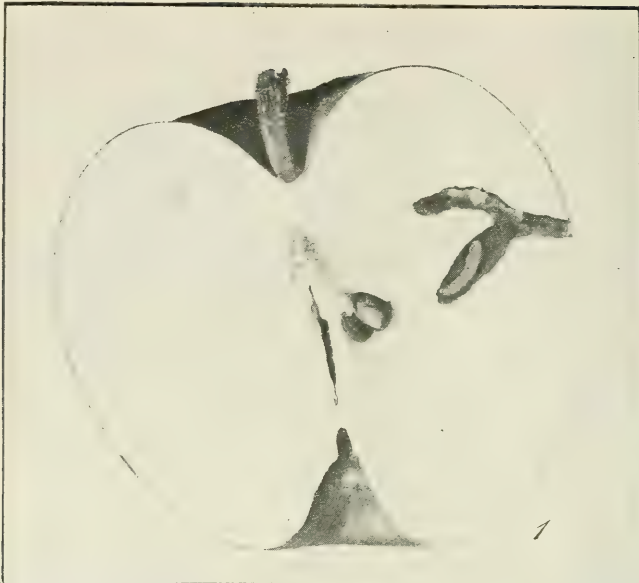
Several European writers have recorded a number of plants, not belonging to the buckwheat family, as food plants, but most of these are doubtful. Brischke (21) mentions loosestrife (*Lythrum salicaria*), and the common pansy (*Viola tricolor*). He was probably mistaken about the latter, in view of the fact that the larvæ of several related sawflies are known to feed on both the pansy and the violet. Kaltenbach (14) mentions goosefoot (*Chenopodium album*) and Laboulbène (16) mentions a reed (*Arundo phragmites*), but a careful reading of their papers shows that they merely found the prepupal larvæ in the stems of these plants, which does not necessarily indicate that they are food plants, as the full-grown larva will bore into any suitable stems, or even rotten wood or soft bark. Kleine (35) found

¹In the summer of 1916, leaves of the common rhubarb and those of a wild species of *Eriogonum* were tested as food for the false-worm larvæ. A number of larvæ of different ages were provided with these leaves, and fresh food was supplied daily. The larvæ fed to some extent, but in a few days all had died, and it seems apparent that the leaves of these plants do not form a suitable food for this insect.



THE DOCK FALSE-WORM (*AMETASTEGIA GLABRATA*).

FIG. 1.—Leaf of dock plant (*Rumex crispus*), showing eggs of dock false-worm in situ. FIG. 2.—The dock false-worm and its injury to foliage of the dock plant; 6th instar larva on the left; on the right, 5th instar larva. FIG. 3.—Adult of dock false-worm on dock leaf. (Original.)



THE DOCK FALSE-WORM.

FIG. 1.—Larval hibernation burrow in mature apple. FIG. 2.—Injury to apples by dock false-worm, and rotting of fruit following injury. (Original.)

larvæ in the stalks of the orache (*Atriplex nitens*), and he states that the larvæ had undoubtedly fed on the pith, though he did not see them doing so, and did not find them feeding on the foliage. The writer has reared over a hundred and fifty larvæ, and has seen them bore into pithy stems, but in no case has he observed the last-stage larva feeding on the pith or on anything else. The borings are invariably pushed past the larva and fill up the burrow behind it. (Fig. 1, *a*.)

In the course of the work with the dock false-worm, larvæ and adult males and females were confined with plants of the common garden beet, with goosefoot (*Chenopodium album*), and with alfalfa, since many prepupal larvæ had been found in dry alfalfa stems. The adult females in every case died without ovipositing, and the larvæ died without feeding on any of the plants, although larvæ transferred from one known food plant to another, as from dock to wild buckwheat, readily adapted themselves to the change.

In feeding on any of these plants, the larvæ devour the leaf tissue and the smaller veins, eating out irregular holes in the leaves. (Pl. I, fig. 2). Ordinarily, the midribs and the larger veins are untouched. If forced to it, however, the larvæ will feed on these, or even on the stem, and sometimes also on the flowering parts.

The dock false-worm must not be confused with the true apple sawfly (*Hoplocampa testudinea* Cameron) of England, which has a whitish larva that lives and feeds in young apples, its feeding habits being similar to those of the related American species, the cherry fruit sawfly (*Hoplocampa cookei* Clarke).

CHARACTER OF INJURY TO APPLES.

The dock false-worm is known to injure apples only in the fall, when the fruit is approaching maturity; that is, in September and October. In orchards under observation the larvæ were present on their food plants throughout the growing season, but no evidence of injury was found that had occurred before the apples had practically stopped growing, with one exception. A single Jonathan was found on October 5, into which a larva had succeeded in burrowing some time before the apple had reached maturity. The apple had grown subsequently and had closed the entrance and squeezed the larva to death. The greater hardness of immature apples probably deters the larvæ from burrowing into them. There were no summer apples in the infested orchards, hence it is not known whether these are ever injured.

The injury to apples consists externally of the small round holes bored by the larvæ, which after a few days show a slightly sunken, brownish ring about them and occasionally may be surrounded by a larger discolored halo. (Pl. II, figs. 1 and 2.) These holes may

occur anywhere on the surface, but are most numerous about the calyx and stem ends, or at a point where the apple touches a leaf or another apple, since it is easier for the larva to obtain a foothold here. Within, the injury is usually more serious, since the larva often burrows to the core and usually hollows out a pupal cell somewhat larger than itself. The burrows vary in length from those just started to holes an inch or two deep. It is quite evident that the larvæ are often not entirely satisfied with the apple as a place of hibernation and that they may begin more than one burrow. Apples frequently have three or four, or sometimes even eight, holes in them of varying depths, but contain only one or two worms, or often none at all. In making counts of apples in connection with control work a record was kept on this point, and it was found that in 207 damaged apples there were 364 holes, each apple having from one to eight holes, and that of the 364 burrows only 66, or a little over 18 per cent, had been completed and contained worms.

The burrow is more or less irregular in outline and may be curved or straight. At its end the larva hollows out the slightly larger pupal cell, turns with its head toward the entrance, and forms a plug across the end of the cell, leaving the outer part of the burrow open. This open burrow affords an easy entrance for mold spores, such as those of the blue mold (*Penicillium*), and the injured fruit frequently starts to rot shortly after being picked, especially if the weather is moist. The larva seems to be well protected against this mold, however, for the fruit tissue immediately surrounding the pupal cell does not rot very readily, but rather becomes dry and pithy. As long as the larva is not actually drowned in the fermenting juices of the rotting fruit it remains alive and healthy. In March, 1915, a number of healthy larvæ were taken from rotten and even mummied Jonathans which had been kept since the preceding September. These larvæ were placed on moist sand, and most of them subsequently pupated and produced adults.

ECONOMIC IMPORTANCE.

Since the dock false-worm does not feed upon any part of the apple tree, but must live upon certain succulent plants, mostly of the buckwheat family, it follows that it can become an apple pest only where these plants are growing in or around the orchard. There can be little or no danger from this insect in clean-cultivated orchards, or in orchards where the food plants do not exist. The possibility of the larvæ coming into the orchard from neighboring meadows, ditch banks, or roadsides is slight, for the larvæ are incapable of finding their way over any extent of bare, cultivated soil. The danger of the larvæ adapting themselves to the apple and feeding upon it is

not to be considered. The apple foliage is so much tougher and dryer than the succulent foliage of the moisture-loving plants upon which they are accustomed to feed that the change of food plants would be practically impossible.

This insect becomes of economic importance, then, only in orchards in which its ordinary food plants are growing, and such orchards would naturally be those that, either through carelessness or because of sod or a cover crop, are not kept clean cultivated. Any orchard kept moist enough to support a cover crop is a favorable place for the food plants of the insect to grow, and since these food plants are widespread, the chances of some one of them, at least, getting into the orchard are very good.

From the description of the injury to apples given above it will be seen that individually this insect is fully as injurious to the fruit as the codling moth, for a single larva will often bore several holes in one apple, and sometimes in several apples, before forming its final burrow. This burrow, too, is often larger than that made by the codling-moth larva and is confined to the flesh of the apple. The tendency of these apples to rot seems to be greater than that of ordinary wormy apples. Collectively, these larvæ have never proved as destructive as many other insects, because they have not been as numerous. It is not inconceivable, however, that they might, under favorable conditions, become a more serious pest.

In the Entiat Valley, Washington, where this insect was chiefly studied, there was a large quantity of wild buckwheat or bindweed (*Polygonum convolvulus*) in the infested orchards, growing in the alfalfa cover crop, and this often was climbing up into the trees for some distance. It can thus be readily seen how the larvæ found their way into the trees and to the fruit. The Jonathan variety was the worst infested, since the tree is of a drooping habit, and the many heavily laden branches, extending down into the alfalfa, afforded the larvæ an easy opportunity to reach the fruit. In the fall of 1914 the extent of injury in one orchard was estimated at about 2 per cent. In 1915 actual counts were made from four representative trees in this orchard, and it was proved that more than 5 per cent of the picked fruit was rendered unmarketable by this worm. This would represent a loss in this particular case of about 16 cents per tree, since the value of the fruit from these trees, which were only 7 or 8 years old, was something over \$3 per tree. This was in spite of the fact that the larvæ had been heavily parasitized the preceding spring. The loss may at times be considerably higher, and, in fact, as already noted, Prof. Melander has written of injuries running as high as 10 per cent.

DESCRIPTION.

THE EGG.

The egg of the dock false-worm is bean shaped or kidney shaped, and somewhat flattened, pearly white, and with a soft, pliable shell. It is protected by the tissues of the leaf in which it is deposited, (Pl. I, fig. 1.) The average length is 0.8 mm., and the width 0.6 mm. About a day before hatching a dark spot shows through, which is one of the eyes of the larva, the head being seen from the side. Shortly before the larva breaks through the shell the outline of the head is discernible.

THE LARVA.

The larva would not ordinarily be noticed on the plants until nearly full grown, and it appears at this time as a slender, hairless larva, with a finely wrinkled olive-green or blue-green skin and a scattering of conspicuous white tubercles. After passing the last molt, which brings it to the stage in which it bores into pithy stems or apples, the larva changes in appearance. (Fig. 2.) It is no longer velvety, but has rather a sleek, shiny appearance, though the wrinkles still persist. Its color is a brighter green—more of an apple green—and the larva seems almost translucent, since the alimentary canal is empty. The tubercles are no longer white and can not be distinguished.

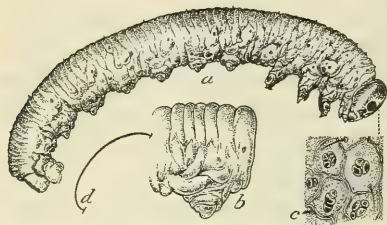


FIG. 2.—The dock false-worm: *a*, Full-grown larva, enlarged; *b*, seventh larval segment, much enlarged; *c*, portion of cranium, highly magnified; *d*, actual length. (Original.)

If an infested stem or apple be cut open, the larva within will be found to have much the same appearance as before it entered, except that it has become shrunken and curved and has lost the power of locomotion. A detailed description of the various larval stages follows:

First instar.—Length, 2.25 mm. General color very light gray; food showing through green. Somewhat slug shaped, thoracic region slightly enlarged, body tapering gradually posteriorly, wrinkled. Head olive brown changing to dark brown, shining; eyes shining black. Just before molting the larva has a shiny, swollen appearance and is somewhat lighter in color.

Second instar.—Length, 4.5 to 5 mm. As before; body wrinkles showing plainly. Head very dark brown, nearly black.

Third instar.—Length, 6 to 8.5 mm. Dorsum greenish gray, merging gradually into the very light yellowish gray of the rest of the body. Body surface wrinkled, dull, numbers of small, sparsely-set setæ being noticeable laterally; surface minutely reticulated, these reticulations being slightly raised and gray dorsally. Head olive brown; mouth parts dark brown; eyes black; thoracic legs same as body, joints marked by dark-brown lines.

Fourth instar.—Length, 9.5 to 14 mm. Dorsum dull bluish green; remainder of body as before. Dorsal surface crossed by whitish lines formed by the wrinkles, and with a scattering of whitish setigerous tubercles. Head light brown, with a dark-brown band dorsally and another crossing the eyes and clypeus. Mouth parts tipped with dark brown.

Fifth instar.—Length, 14 to 17.5 mm.; width of thorax, 2 mm. Body of 13 segments, cylindrical, slightly enlarged in the thoracic region. Integument considerably wrinkled, and with a very finely shagreened surface, which gives the larva a velvety appearance. Dorsal region to the line of the spiracles distinct olive green or occasionally bluish green; ventral region very light yellowish, color changing abruptly at spiracular line.

The dorsal olive-green region appears to be crossed by more or less irregular whitish lines, due to the cuticular folds or wrinkles, and laterally this dark region is even darker, as the raised shagreening is black. The dorsal vessel shows through as a dark-green line. The prothoracic segment is provided with four whitish setigerous tubercles on each side, three of them being in the dark dorso-lateral region and one just above the leg. The other thoracic segments have seven tubercles on each side, having, besides those mentioned above, two near the dorsal line and one latero-ventrally, near the anterior margin of the segment. The abdominal segments, also, have seven tubercles, in slightly different positions, except the last segment, which has only one tubercle on each side of the dorsal line. The anal region is covered with small setæ.

Head narrower than thorax, minutely punctured, sparsely covered with setæ, light brown, a dorsal transverse band of dark brown, incised on the dorsum posteriorly by a triangle of light brown, at each side of which is a distinct, short, longitudinal suture. Dorsal part of clypeus, tips of mandibles, palpi, and antennæ brown. Eyes very dark brown. Abdominal legs, eight pairs, concolorous with venter; thoracic legs, three pairs, the same but somewhat more heavily chitinized, and with the joints marked by brown lines.

Sixth instar.—Length, 14.5 to 16 mm.; width of thorax, 2 mm. (length of parthenogenetic larvæ, 8 to 12 mm.). Similar to fifth-instar larva in shape and skin texture. Color of dorsal region apple green or pale green; ventral region light yellow. Dorsal vessel showing through whitish or yellowish. No dark contents of alimentary canal. The whitish tubercles have disappeared, but the setæ can still be made out in the same positions.

Head covered with small, irregularly rounded, slightly raised, smooth spots, interspersed with raised dots. The spots, when strongly magnified, seem to be made up of two or three cells, this appearance evidently being due to darker markings just beneath the surface. Color of ventral part very light brown, dorsal part, above eye, dark olive brown; clypeus olive brown; tips of mandibles, palpi, and antennæ reddish brown; eyes black.

Prepupal larva.—Length, 6 to 13 mm., average, 10 mm.; male larva smaller than female; cylindrical, somewhat curved dorso-ventrally, shrunken. Body surface wrinkled. Color unchanged.

THE PUPA.

Length, male, 7 to 8 mm.; female, 9 to 11 mm. Elongate, slim, the male smaller than the female and more slender. Sexes distinguished by appearance of tip of abdomen, the female saws being very distinct. Dorsal region apple green. Head, appendages, and ventral and lateral surfaces up to spiracular line, light translucent whitish or yellowish, sometimes with a greenish tinge. Eyes reddish brown.

After a few days the head and thorax become black-brown, and shortly before the adult emerges, the eyes, head, antennæ, thorax, and abdominal plates are jet black, the membrane between the plates being light greenish. The legs are light ferruginous, except the metatarsi, which are black, and the distal tips of the protarsi and mesotarsi, which are dark brown.

THE ADULT.

The adult sawfly (fig. 3; Pl. I, fig. 3) is a slender, blue-black, wasp-like insect, with reddish legs. At first glance it may be mistaken for an ichneumon fly, but it will be distinguished readily by its thicker and heavier abdomen, its relatively shorter antennæ, and in the female by its lack of the usual long, conspicuous ovipositor of the ichneumon fly. The males and females are similar, the males averaging smaller. The description given for *Tuxonus nigrisoma* by Norton (8) characterizes the adult very well, and is given herewith:

Blue black, the legs dark rufous; length 0.30, breadth of wings 0.60 inch. Color blue black; abdomen rather long, flattened, acute; antennæ slender, basal joint enlarged, third longer than fourth; apical joint as long as the preceding; clypeus angulate emarginate; labrum and base of mandibles pale rufous; legs rufous or honey yellow; base of coxæ and tarsi black; wings faintly clouded, stigma and costa black.

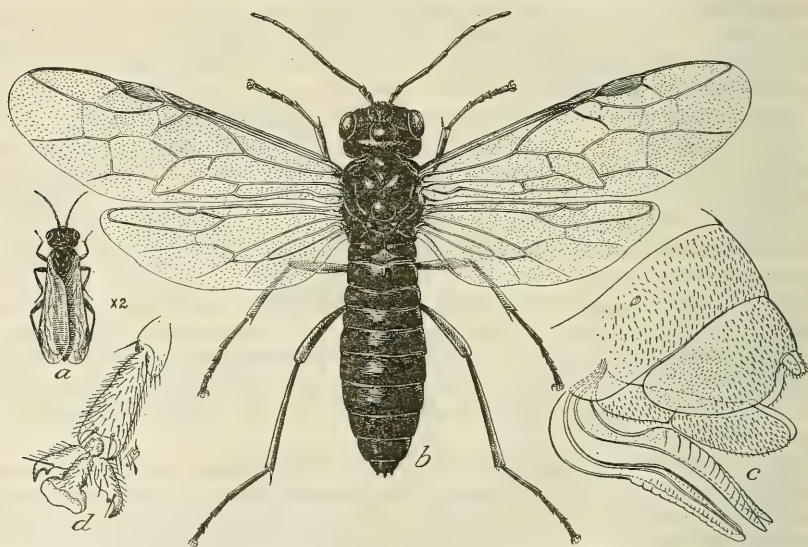


FIG. 3.—The dock false-worm: a, Adult fly, twice enlarged; b, adult female, much enlarged; c, anal segments of female showing ovipositor; d, tarsus of hind leg of female. (Original.)

LIFE HISTORY AND HABITS.

METHODS OF STUDY.

In studying the life history of the dock false-worm, rearings were made in an outdoor insectary with a roof but no sides. In order to rear the larvæ under conditions as nearly normal as possible, they were kept on living plants. Small plants of the common curly dock (*Rumex crispus*) and of the wild buckwheat (*Polygonum convolvulus*) were potted in tin cans. After being kept in a cool place for a few days, with plenty of water, these plants appeared normal and made regular growth throughout the season, some of them even producing flowering stalks. The dock plants were by far the most

satisfactory, since they were more easily kept within bounds and their fewer and larger leaves made it easier to locate the larvæ. Oviposition records were obtained by confining freshly emerged adult flies, either pairs or single females, in inverted lantern chimneys placed over these plants and closed at the top by pieces of cheesecloth held in place by rubber bands. A few records, also, were obtained in larger cloth-covered rearing cages. The adults were transferred, usually every day or two, to fresh plants, in order to ascertain more exactly the incubation period of the eggs. These were examined every morning, and the larvæ, as they hatched, were transferred to other plants, or, if not required, were destroyed, because, if left on the same plant, they frequently ate into the unhatched eggs. Several larvæ were ordinarily placed on each plant, since the young ones sometimes fell off and were lost. There was a great regularity in the early molts, making them easy to keep track of, and as the larvæ grew larger they were moved to new plants, only one or two being kept on a plant. The larvæ showed little inclination to wander, and the plants were left uncovered on the shelves. As the larvæ neared the final stage, however, a lantern chimney was inverted over the plant, and several pithy stems, such as those of wild mustard, were placed in the chimney for them to burrow into. However, if the larvæ were discovered just after the last molt, they were transferred to cotton-stoppered glass vials with one of the stems, since they sometimes burrowed into the ground instead of into the stems. Pupation was observed by splitting open the stems a few days after the larvæ had entered. This did not affect them at all, except that during the hot, dry weather they showed a tendency to dry up and die, either before or after pupating. This was avoided by moistening the cotton plugs and by keeping the vials in an improvised moist chamber made of a large lard can. Experiments showed that this did not materially affect the pupal period; indeed, the presence of moisture is undoubtedly a normal condition, since the dead stems in which the larvæ naturally pupate must lie on or near the moist soil in which the food plant is growing. These careful laboratory studies were supplemented by observations in the field, covering chiefly the natural habits of the insect.

NUMBER OF GENERATIONS.

Four generations of the dock false-worm have been distinguished. The generations overlap and become somewhat confused, the reason being apparent when it is noted that the emergence from overwintering larvæ of the spring brood of adult flies in 1915 covered a period of seven weeks, namely, from April 13 to June 4, with a single emergence on June 16. In rearing this insect, it was planned to carry a genealogical series through the season. This attempt was only partially successful, since the hot, dry weather of the latter part of July

cut off the adult emergence of the second generation to a great extent, and, while a number of males were secured, only a single female emerged. The offspring from this female were successfully carried through, however, to four complete generations, the larvæ of the fourth generation, of course, hibernating in their pupal cells and forming spring-brood pupæ and adults the following year. Additional records were obtained by collecting eggs in the field at the time the second-brood adults were emerging and rearing the larvæ from these eggs. It is reasonable to suppose that these eggs were deposited by second-brood adults, since they were collected after July 15, and no spring-brood adults had emerged from the overwintering material after June 16. In selecting adults for oviposition in the insectary, those emerging early and late were, if possible, disregarded, and only those emerging during the period of maximum emergence were used.

Since it was not possible to rear a sufficient quantity of the false-worms to get an adequate idea of the time when each generation occurred in maximum numbers, field observations were made from July 1 to September 8, once a week or oftener. This work was done near the field station at Wenatchee, Wash. As many worms as could be found in a couple of hours were observed, and the instar or stage in each case was recorded. From these figures the percentage of each instar for each date was worked out, thus indicating the broods. Since the infestation was not great enough near Wenatchee to afford a large number of worms for examination at each date, the number running from 20 to 100, the detailed figures are not given here. The diagram in figure 4, however, shows graphically the percentage of full-grown larvæ found on each date. As these figures do not cover the whole season, the lower line is added to the diagram to show the actual number, and not the percentage, of first and second brood larvæ passing the final molt each day, from among those reared at the laboratory. It will be seen that where these two lines overlap they correspond fairly well, and the two together show at a glance when the larvæ of each generation attain maturity. The curves are shown for the mature larvæ, since these are the only ones that ever injure fruit.

HABITS.

Since the habits of the individuals of all generations of the dock false-worm are the same, they will not be considered separately. As we have already indicated, the eggs are deposited in the leaf tissue of the food plants (Pl. I, fig. 1). The larvæ, in escaping, eat a small circular hole through the eggshell and the thin epidermis of the leaf, usually the lower, and crawl out. They begin to feed at once, finding a secure foothold on the rough lower surface of the leaf. At first they eat only through to the upper epidermis, leaving this intact as a thin membrane, but after passing the first molt they begin to eat clear through the leaf, forming irregular holes.

The larvæ molt five times, passing through six stages or instars. During the first and second instars, or until the second molt, the larvæ usually remain on the same leaf. After this they become more or less restless and find their way to other leaves, especially if the first leaf has been supporting several larvæ and is mostly eaten. The younger larvæ lie securely in the hollows they have eaten out of the leaf, clinging to the lower side of the upper epidermis, and they are not easily dislodged. The large larvæ simply lie at full length on the under surface, and if disturbed, curl up the posterior part of the body, holding to the leaf only by the thoracic legs. If the disturbance continues they loosen their hold and drop to the ground, later finding their way back to the leaves. This death feigning, if it may be so called, is a characteristic of this type

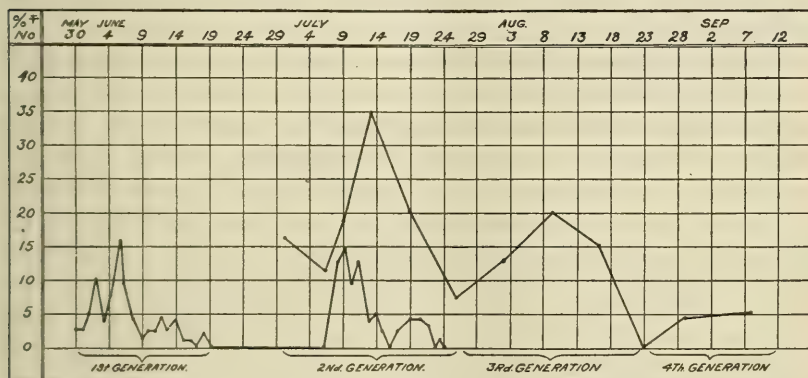


FIG. 4.—The dock false-worm: Diagram showing seasonal abundance of the generations. (Original.)

of sawfly larva, and where the larvæ are numerous a veritable shower of them will be produced by shaking the plants.

The larva ordinarily molts on the leaf where it has been feeding, but sometimes it will migrate to the leaf stem or the base of the plant. It remains quiet for a time before molting, and then the usual peristaltic motion is noticeable. The integument of the head soon splits along the dorsal line to the clypeus, the split forking here and following the clypeal sutures. This frees the head of the larva, which is pushed out, followed by the thorax, and a little time elapses before the mouth parts and thoracic legs are pulled out of their old coverings. Since the posterior part of the old skin is attached to the leaf by means of the hooks on the abdominal legs, the larva is soon able to crawl out, the whole operation occupying six or eight minutes. After molting the larva rests for 10 or 15 minutes in order to allow the new integument to harden somewhat, whereupon it is ready to feed again. The molted integument is not eaten, but remains adhering to the leaf or stem.

No food is taken by the larva after passing the fifth molt and entering the sixth or last instar. The larva usually remains quiet for a time after this molt, as after the others, and then begins to search for a suitable place in which to pupate. This, as a rule, is a dry, pithy stem, such as the flowering stalk of the dock or pigweed, or a dry alfalfa stem. It will also bore into rotten wood or soft bark, if nothing better is available, and, under laboratory conditions at least, will occasionally burrow into the moist earth at the base of the plant. Upon finding a suitable stem the larva at once commences to burrow into it. If the stem has been cut, as may frequently be the case with alfalfa, the larva burrows into the pith at the cut end and soon disappears. Otherwise, it burrows directly into the side of the stem, cutting out a circular hole and then hollowing out the pith within the stem, working the pieces back to the opening with the feet (fig. 1).

The larva burrows an inch or more from the opening and hollows out a pupal cell somewhat larger than itself. When this is accomplished the larva turns around within the cell, returns to the opening, and caps it over with a regurgitated, translucent, mucilaginous substance, mixed with bits of pith. This substance is smeared around the edge of the opening, the mouth parts and fore legs aiding in the process, and the head is moved back and forth until the hole is closed. After this the larva can be seen for a time through the cap, but as the latter is thickened from within the actions of the larva become indistinguishable. The larva then gives its attention to the pupal cell, cleaning it out and often filling up the burrow behind it with pith. A specially compacted mass or plug of pith is formed at the entrance to the pupal cell, as an additional protection, and after completing this the activities of the larva are over, and it soon becomes shrunken and capable of only a slight squirming motion.

The amount of time consumed in making this burrow and forming the pupal cell naturally varies with the condition of the wood, but it usually occupies six or eight hours, unless the larva bores into the cut end of a stem, when the time is considerably shortened. One larva under observation started to bore into the side of a stem at 11.15 a. m., and began to cap the opening at 4.35 p. m. The opening was closed at 5 p. m., and the larva undoubtedly took some time subsequently to complete the burrow. Another larva started its second burrow at noon, after having worked three and a half hours on the first, only to find the stem already occupied, and completed it by 6 p. m. In the breeding cages, where pithy stems were always available for the larvæ, they almost invariably had completed their burrows within 24 hours after the last molt. The larvæ of the summer generations remain in this cell six or eight days before pupating, while the larvæ of the last generation pass the winter here, remaining in the cell six months or more.

In collecting these wintering larvæ in the spring it was observed that when a larva bored into the side of a stem it always formed its pupal cell below the entrance, unless the stem lay in a horizontal position, when it might go either way. In nearly all cases, but not invariably, the head of the larva lies toward the entrance, so that escape may be facilitated. Where the insect is common, more than one larva will frequently be found in one stem, and sometimes as many as four, or five, or even eight. It sometimes happens that a larva in forming its cell pushes the lower plug down too tightly on the larva below, with the result that the latter is killed.

The pupa is able to wriggle about in its cell to some extent but does not force its way out to the entrance when the adult is ready to emerge, as is the case with many wood-boring insects. Several hours before emerging the legs, mandibles, and labrum become somewhat freely movable, with the strengthening of the adult muscles within. After casting the pupal skin the adult sometimes lies in its cell for a day or two, especially if the weather is unfavorable (fig. 1, *b*). It escapes through the original entrance, biting a hole in the cap. If two or more adults are confined in a single vial for several days after emergence they often mutilate each other, sometimes biting off all the appendages.

The adult flies are quite active and take flight readily. They spend their time flying and crawling about over the larval food plants and the neighboring vegetation, and it is unlikely that they get very far from their birthplace, unless carried by the wind or some other agency. Copulation has not been observed, although numbers of pairs were under observation in breeding jars. No food was observed to be taken, except that the adults occasionally lapped up the little moisture that occurred on the leaves.

The female usually oviposits from the upper side of the leaf, and the egg appears below, very close to the epidermis, in a raised blister about 1.2 mm. long. The ovipositor (fig. 3, *c*, and fig. 5) is thrust into the leaf and gradually worked around to one side by a sawing motion until a nearly circular cell is cut between the upper and lower leaf epidermis. When this is completed, the ovipositor is slowly removed as the egg is deposited. In eight timed ovipositions the operation occupied from 25 to 75 seconds, with an average of 45 seconds. Frequently the eggs are laid in chains, the female after laying one merely moving forward a little and depositing another. Oviposition ordinarily begins within a day after emergence and continues for several days, the majority of eggs, however, being deposited the first two or three days.

PARTHENOGENESIS.

Parthenogenesis—that is, the production of young from unfertilized eggs—has long been known to occur among the sawflies, and the males are ordinarily less common than the females. This partheno-

genesis may take one of several forms. Unfertilized females will deposit eggs which either will not hatch or will hatch and the resulting larvæ will die before attaining maturity, or the larvæ from such eggs will produce only male adults. The dock false-worm belongs to the latter class, the unfertilized females ovipositing normally and the eggs hatching and ultimately producing males.

Great care was taken in rearing the dock false-worm to ascertain the status of parthenogenesis in this species. Single pupæ were kept separate in glass vials, and females emerging from them were confined alone with the larval food plant. They appeared as eager to oviposit as those confined with males, and the average number of eggs deposited

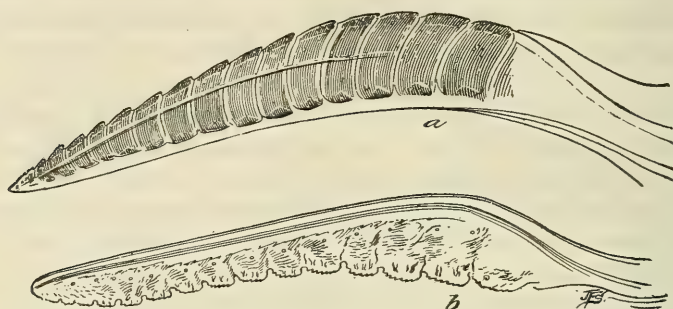


FIG. 5.—The dock false-worm: *a*, Superior saw blade of the ovipositor of adult female; *b*, inferior blade of ovipositor. Highly magnified. (Original.)

by them was greater than that deposited by mated females. The period of development of all stages, as a rule, averaged somewhat shorter than that of normal individuals, comparison, of course, being made only with normal males developing under identical conditions. The figures for parthenogenetic individuals of the various broods are given below, under the heading "Life-history studies," where they are kept separate from the figures for normal individuals. Table I compares the period of development of normal males and parthenogenetic males of the first, second, and fourth generations. No parthenogenetic individuals of the third generation were reared.

TABLE I.—Comparison of life cycle of normal and parthenogenetic males of the dock false-worm, Wenatchee, Wash., 1915.

Generation.	Origin of males.	Average number of days in—			
		Egg stage.	Larval stage.	Pupal stage.	Total life cycle.
First	Normal	11.5	33.6	5.5	50.7
	Parthenogenetic	11.2	29.7	5.2	46.1
Second	Normal	6.0	20.9	5.4	32.3
	Parthenogenetic	4.2	20.6	6.3	31.1
Fourth	Normal	4.8	27.8	.....	32.6
	Parthenogenetic	5.8	26.8	.....	32.6

LIFE-HISTORY STUDIES.

The life-history records given below include records of both normal and parthenogenetic individuals. Where both records occur, these are kept separate, since the normal proportion of individuals of parthenogenetic origin in nature is not known. Records of normal males and females are also kept separate in the complete life-cycle tables, except in the table referring to the fourth generation, the individuals of this generation being still in the larval stage at the time of writing.

SPRING BROOD OF PUPÆ AND ADULTS.

Pupal period.—The pupation records of the spring brood of pupæ and the subsequent emergence of the adults were obtained from the overwintering material collected in the Entiat Valley, Wash., on March 17, 1915. Table II gives the length of the pupal period of 40 males and 71 females of the spring brood of pupæ. The average pupal period for males of this brood is 10.2 days, and for the females 10.6 days.

TABLE II.—Length of pupal period of spring-brood pupæ of the dock false-worm, Wenatchee, Wash., 1915.

Males.					Females.				
Number of individuals.	Date of—		Days—		Number of individuals.	Date of—		Days—	
	Pupa- tion.	Emer- gence.	Each.	Total.		Pupa- tion.	Emer- gence.	Each.	Total.
1	Mar. 31	Apr. 13	13	13	1	Mar. 31	Apr. 14	14	14
1	do.	Apr. 14	14	14	2	Apr. 7	Apr. 18	11	22
1	Apr. 5	Apr. 18	13	13	1	Apr. 8	do.	10	10
1	Apr. 6	do.	12	12	3	Apr. 10	Apr. 19	9	27
1	Apr. 7	do.	11	11	1	Apr. 11	do.	8	8
2	Apr. 8	Apr. 19	11	22	2	Apr. 12	Apr. 20	8	16
2	Apr. 9	do.	10	20	1	do.	Apr. 21	9	9
2	Apr. 10	do.	9	18	1	Apr. 13	Apr. 22	9	9
3	Apr. 11	do.	8	24	7	do.	Apr. 23	10	70
1	Apr. 12	do.	7	7	1	do.	Apr. 24	11	11
4	do.	Apr. 21	9	36	5	Apr. 14	Apr. 23	9	45
1	do.	Apr. 23	11	11	4	do.	Apr. 24	10	40
3	Apr. 13	do.	10	30	1	do.	Apr. 25	11	11
2	do.	Apr. 24	11	22	2	Apr. 15	do.	10	20
1	Apr. 14	Apr. 23	9	9	3	Apr. 16	do.	9	27
2	do.	Apr. 24	10	20	4	do.	Apr. 26	10	40
1	do.	Apr. 25	11	11	4	Apr. 17	do.	9	36
1	Apr. 15	Apr. 26	11	11	7	do.	Apr. 27	10	70
2	Apr. 16	do.	10	20	1	do.	Apr. 28	11	11
3	Apr. 17	Apr. 27	10	30	1	Apr. 18	Apr. 27	9	9
1	do.	Apr. 28	11	11	2	do.	Apr. 28	10	20
2	Apr. 19	Apr. 29	10	20	3	do.	Apr. 29	11	33
1	Apr. 23	May 5	12	12	2	Apr. 19	do.	10	20
1	Apr. 24	May 6	12	12	2	do.	May 2	13	26
40				411	1	do.	May 4	15	15
Average length in days.....				10.2	1	Apr. 20	do.	14	14
Maximum.....				14	2	Apr. 21	May 5	14	28
Minimum.....				7	1	Apr. 24	May 6	12	12
					1	Apr. 26	May 8	12	12
					2	Apr. 27	do.	11	22
					1	May 4	May 18	14	14
					1	June 9	June 16	7	7
					71				758
Average length in days.....				10.6					
Maximum.....				15					
Minimum.....				7					

Emergence of spring-brood adults.—Table III gives the time of emergence of 201 adult male and female sawflies of the spring brood, including those hibernating both in stems and in apples. The emergence covers a period of over seven weeks, disregarding the single female that emerged on June 16, but the maximum emergence occurred on April 23, only 10 days after the first emergence.

TABLE III.—*Time of emergence of spring-brood adults of the dock false-worm, Wenatchee Wash., 1915.*

Date.	Number of—		Total number.	Date.	Number of—		Total number.
	Males.	Females.			Males.	Females.	
Apr. 13.....	1	0	1	May 2.....	1	2	3
Apr. 14.....	1	1	2	May 4.....	2	2	4
Apr. 15.....	1	0	1	May 5.....	1	5	6
Apr. 16.....	1	0	1	May 6.....	1	1	2
Apr. 18.....	3	3	6	May 7.....	1	5	6
Apr. 19.....	14	4	18	May 8.....	0	3	3
Apr. 20.....	6	10	16	May 18.....	0	1	1
Apr. 21.....	5	1	6	May 19.....	1	2	3
Apr. 22.....	4	1	5	May 20.....	1	0	1
Apr. 23.....	12	17	29	May 21.....	0	1	1
Apr. 24.....	7	6	13	May 24.....	0	1	1
Apr. 25.....	2	10	12	May 27.....	1	1	2
Apr. 26.....	7	14	21	June 4.....	0	3	3
Apr. 27.....	3	11	14	June 16.....	0	1	1
Apr. 28.....	2	7	9				
Apr. 29.....	3	7	10	Total.....	81	120	201

Length of life of spring-brood adults.—Table IV gives the length of life of 7 males and 11 females confined in lantern chimneys placed over the larval food plant.

TABLE IV.—*Length of life of spring-brood adults of the dock false-worm, Wenatchee, Wash., 1915.*

Males.					Females.				
Number of individuals.	Date—		Days—		Number of individuals.	Date—		Days—	
	Emerged.	Died.	Each.	Total.		Emerged.	Died.	Each.	Total.
1	Apr. 23	May 8	15	15	3	Apr. 23	May 8	15	45
1	do	May 9	16	16	3	Apr. 24	May 5	11	33
1	Apr. 24	Apr. 28	4	4	1	Apr. 28	May 8	10	10
2	do	May 5	11	22	1	do	May 9	11	11
1	Apr. 28	May 8	10	10	1	do	May 13	15	15
1	Apr. 29	May 21	22	22	1	do	May 15	17	17
					1	May 2	May 14	12	12
7				89	11				143
Average number of days.....				12.7	Average number of days.....				13.0
Maximum.....				22	Maximum.....				17
Minimum.....				4	Minimum.....				10

There is little difference between the length of life of the males and females, the average being 12.8 days, and it is probable that adults in the open would average about the same. Thirty-five adults were confined in the glass vials in which they emerged, with no food or moisture, and these lived an average of only 8.3 days.

Oviposition of spring-brood adults.—Spring-brood adults begin ovipositing within a day of emergence. The maximum period observed was 9 days, with an average of 2.9 days, figuring from date of emergence to date of deposition of each egg. Six mated females of the spring brood deposited an average of 103.6 eggs, the maximum being 117 and the minimum 89; five single females deposited an average of 109.4 eggs, with a maximum of 125 and a minimum of 102.

FIRST GENERATION.

Incubation period of first-brood eggs.—Table V gives the length of the egg stage for 446 fertile eggs and 301 parthenogenetic eggs deposited by spring-brood females in living plants. The fertile eggs of this brood have an average incubation period of 10.7 days, as against 9.9 days for the parthenogenetic eggs.

TABLE V.—Length of the incubation period of first-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.

Fertile eggs.					Parthenogenetic eggs.				
Number of eggs.	Date—		Incubation period.	Total days.	Number of eggs.	Date—		Incubation period.	Total days.
	Deposited.	Hatched.				Deposited.	Hatched.		
28	Apr. 25-26.....	May 7	11.5	332	86	Apr. 29.....	May 9	10	860
5	do.....	May 8	12.5	62.5	10	do.....	May 10	11	110
98	Apr. 25-27.....	May 7	11	1,078	1	do.....	May 11	12	12
44	do.....	May 8	12	528	1	do.....	May 12	13	13
7	do.....	May 9	13	91	1	do.....	May 15	16	16
43	Apr. 28-29.....	May 8	9.5	408.5	12	Apr. 29-May 5	May 13	11	132
102	do.....	May 9	10.5	1,071	9	do.....	May 14	12	108
6	do.....	May 10	11.5	69	16	May 5-9.....	May 15	8	128
25	Apr. 29.....	May 9	10	250	1	do.....	May 16	9	9
4	do.....	May 10	11	44	6	do.....	May 17	10	60
2	do.....	May 11	12	24	5	do.....	May 18	11	55
1	do.....	May 13	14	14	2	do.....	May 19	12	24
12	Apr. 30-May-5.	May 11	8.5	102	12	May 5-8.....	May 14	7.5	90
8	do.....	May 12	9.5	76	31	do.....	May 15	8.5	263.5
50	do.....	May 13	10.5	525	8	do.....	May 16	9.5	76
9	do.....	May 15	12.5	112.5	21	do.....	May 17	10.5	220.5
1	May 5.....	May 16	11	11	16	do.....	May 18	11.5	184
1	do.....	May 17	12	12	8	do.....	May 19	12.5	100
446				4,800.5	4	May 9.....	do.....	10	40
Average incubation period.....				10.7	3	do.....	May 21	12	36
Maximum.....				14	2	do.....	May 24	15	30
Minimum.....				6	38	May 25.....	June 3	9	342
					5	May 26.....	June 4	9	45
					3	do.....	June 5	10	30
					301				2,984
					Average incubation period.....				9.9
					Maximum.....				16
					Minimum.....				6

Length of life of first-brood larvae by instars.—Seventy larvae from fertile eggs were reared, at least to the third instar, but of these only 31 were carried to the pupal stage. A partial record was obtained of 19 parthenogenetic larvae, and a complete record of 8. Table VI gives a summary of the length of larval life by instars, of all larvae reared.

TABLE VI.—*Summary of larval life of first generation of the dock false-worm by instars, Wenatchee, Wash., 1915.*

Normal larvæ.																	
First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
21	4.5	94.5	1	2	2	1	2	2	4	2	8	1	1	1	5	5	25
3	5	15	4	3	12	7	3	21	5	3	15	1	2	2	7	6	42
1	6	6	16	4	64	28	4	112	30	4	120	2	3	6	6	7	42
8	6.5	52	2	4.5	9	20	5	100	18	5	90	4	4	16	3	8	24
11	7	77	21	5	105	6	6	36	3	6	18	12	5	60	5	9	45
2	7.5	15	2	5.5	11	5	7	35	3	7	21	16	6	96	1	11	11
3	8	24	19	6	114	2	8	16	1	8	8	9	7	63	1	12	12
12	8.5	102	2	6.5	13	1	12	12	1	10	10	6	8	48	1	13	13
3	9.5	28.5	2	7	14							1	9	9	1	17	17
1	10	10	1	8	8	70	.....	334	65	.....	290	4	10	40	1	23	23
2	10.5	21				Av.	.....	4.7	Av.	.....	4.4	3	11	33			
2	11	22				Max.	.....	12	Max.	.....	10	3	12	36	31	.....	254
						Min.	.....	2	Min.	.....	2				Av.	.....	8.2
69		467	Av.	.....	5							62		410	Max.	.....	23
Av.	.....	6.7	Max.	.....	8							Av.	.....	6.6	Min.	.....	5
Max.	.....	11	Min.	.....	2							Max.	.....	12			
Min.	.....	4.5										Min.	.....	1			

Parthenogenetic larvæ.																	
First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	2.5	2.5	4	3	12	1	3	3	2	2	4	3	1	3	1	5	5
2	4	8	10	4	40	16	4	64	6	3	18	3	2	6	2	7	14
1	5	5	5	5	25	1	5	5	4	4	16	3	3	9	5	8	40
2	6	12				1	6	6	4	5	20	4	5	20			
2	6.5	13	19	.....	77				16	.....	58	1	8	8	8	.....	59
2	7	14	Av.	.....	4	19	.....	78	Av.	.....	3.6				Av.	.....	7.4
6	7.5	45	Max.	.....	5	Av.	.....	4	Av.	.....	5	14	.....	46	Max.	.....	8
2	8	16	Min.	.....	3	Max.	.....	6	Max.	.....	2	Av.	.....	3.3	Min.	.....	5
1	8.5	8.5				Min.	.....	3	Min.	.....	2	Max.	.....	8			
												Min.	.....	1			
19		124															
Av.	.....	6.5															
Max.	.....	8.5															
Min.	.....	2.5															

Length of life of first-brood pupæ.—Records of the pupal period were obtained from 10 parthenogenetic pupæ, 9 normal male pupæ, and 22 female pupæ, and a summary of these records is given in Table VII.

TABLE VIII.—*Length of life cycle of the first generation of the dock false-worm, Wenatchee, Wash., 1915—Continued.*

Females.								
Individual No.	Date of—				Days in—			Total life cycle in days.
	Egg deposition.	Hatching.	Pupa- tion.	Emer- gence.	Egg stage.	Larval stage.	Pupal stage.	
1	Apr. 25	May 7	June 8	June 15	12	32	7	51
2	do.	do.	do.	June 16	12	32	8	52
3	do.	do.	June 10	do.	12	34	6	52
4	do.	do.	do.	do.	12	34	6	52
5	do.	do.	June 13	June 18	12	37	5	54
6	do.	do.	June 22	June 28	12	46	6	64
7	Apr. 27	May 8	June 12	June 17	11	35	5	51
8	do.	do.	June 15	June 20	11	38	5	54
9	Apr. 28	May 9	June 21	June 21	11	37	6	54
10	do.	do.	do.	do.	11	37	6	54
11	do.	do.	June 18	June 23	11	40	5	56
12	do.	do.	June 20	June 26	11	42	6	59
13	do.	do.	June 24	June 29	11	46	5	62
14	Apr. 30	May 11	June 17	June 23	11	37	6	54
15	do.	do.	June 18	June 24	11	38	6	55
16	do.	do.	do.	do.	11	38	6	55
17	do.	do.	June 20	June 25	11	40	5	56
18	do.	do.	June 22	June 28	11	42	6	59
19	May 8	May 21	June 18	June 23	13	28	5	46
20	do.	May 23	do.	do.	15	26	5	46
21	do.	May 24	June 27	July 1	16	34	4	54
22	do.	May 25	July 1	July 6	17	37	5	59
Total.....					265	810	124	1199
Average number of days.....					12.0	36.8	5.6	54.5
Maximum life cycle, 64 days; minimum, 46 days.								
Normal average life cycle.....					10.7 ¹	35.9	5.6	53.4

¹ Taken from Table V.

The parthenogenetic life cycle averages 46.1 days, the life cycle of normal males, 50.7 days, and the female life cycle, 54.5 days. The average life cycle of normal individuals of both sexes is 53.4 days.

Length of life of first-brood adults.—The warmer weather at the time the first-brood adults are flying appears to reduce the length of their lives, and the average of six adults was 5.3 days, with a minimum of 3 days and a maximum of 7 days.

Oviposition of first-brood adults.—Oviposition begins, in the case of first-brood females, sometimes within a few hours after emergence, and the maximum period observed was 5 days, with an average of 1.7 days. Eggs were secured from six mated females, the average number being 62.3, with a maximum of 92, and a minimum of 39; four single females deposited an average of 67.7 eggs, with a maximum of 90, and a minimum of 46. These females, being reared at the laboratory from eggs deposited there by females of the previous brood, may not have been quite as vigorous as those in nature, which may account for the smaller number of eggs.

SECOND GENERATION.

Incubation period of second-brood eggs.—The length of the second-brood egg stage is shorter than that of the first, owing to the warmer weather at this time, the fertile eggs having an average incubation period of 4.8 days, and the parthenogenetic eggs an average period of 4.3 days. The records for 238 fertile eggs and 202 parthenogenetic eggs are given in Table IX.

TABLE IX.—Length of the incubation period of second-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.

Fertile eggs.					Parthenogenetic eggs.				
Number of eggs.	Date—		Incubation period.	Total days.	Number of eggs.	Date—		Incubation period.	Total days.
	De- posited.	Hatched.				De- posited.	Hatched.		
17	June 20	June 26	6	102	29	June 20	June 25	5	145
9	June 21	..do....	5	45	1	..do....	June 27	7	7
1	..do....	June 27	6	6	53	June 21	June 26	5	265
9	June 22	..do....	5	45	2	..do....	June 27	6	12
27	..do....	June 28	6	162	3	..do....	June 28	7	21
18	..do....	June 29	7	126	6	June 22	June 27	5	30
7	June 23	..do....	6	42	14	..do....	June 28	6	84
14	June 29	July 2	3	42	4	June 23	June 29	6	24
56	..do....	July 3	4	224	7	June 29	July 2	3	21
3	June 30	..do....	3	9	64	June 30	July 3	3	192
34	July 3	July 7	4	136	5	..do....	July 4	4	20
34	..do....	July 8	5	170	9	July 1	..do....	3	27
1	..do....	July 9	6	6	3	..do....	July 5	4	12
5	July 4	..do....	5	25	1	..do....	July 6	5	5
1	..do....	July 10	6	6	1	July 2	..do....	4	4
2	..do....	July 11	7	14					
238				1,160	202				869
Average incubation period.....				4.8	Average incubation period.....				4.3
Maximum.....				7	Maximum.....				7
Minimum.....				3	Minimum.....				3

Length of life of second-brood larvæ by instars.—Of 43 larvæ which were reared from fertile eggs only 17 reached the pupal stage. The greatest mortality, due to lack of moisture, occurred after the mature larvæ had formed their pupal cells. Forty-seven parthenogenetic larvæ were reared, 6 of them pupating. Table X gives a summary of the length of larval life of all larvæ reared.

TABLE X.—*Summary of larval life of second generation of the dock false-worm, by instars, Wenatchee, Wash., 1915.*

Normal larvæ.																	
First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	1	1	24	1	24	13	1	13	3	1	3	10	3	30	1	5	5
5	2	10	14	2	28	25	2	50	22	2	44	14	4	56	4	6	24
16	3	48	4	3	12	3	3	9	12	3	36	8	5	40	6	7	42
18	4	72	1	4	4	1	4	4	4	4	16	6	6	36	4	9	36
3	5	15				1	6	6	1	5	5	1	8	21	2	10	20
43		146	43		68	43		82	42		104	42		191	17		127
Av.	3.4		Av.	1.6		Av.	1.9		Av.	2.5		Av.	4.5		Av.	7.4	
Max.	5		Max.	4		Max.	6		Max.	5		Max.	8		Max.	10	
Min.	1		Min.	1		Min.	1		Min.	1		Min.	3		Min.	5	
Parthenogenetic larvæ.																	
17	3	51	16	1	16	7	1	7	4	1	4	1	2	2	4	7	28
22	4	88	27	2	54	34	2	68	21	2	42	9	3	27	1	8	8
8	5	40	4	3	12	6	3	18	18	3	54	20	4	80	1	13	13
									3	4	12	6	5	30			
												7	6	42			
												3	7	21			
47		179	47		82	47		93	46		112	46		202	6		49
Av.	3.8		Av.	1.7		Av.	2		Av.	2.4		Av.	4.4		Av.	8.1	
Max.	5		Max.	3		Max.	3		Max.	4		Max.	7		Max.	13	
Min.	3		Min.	1		Min.	1		Min.	1		Min.	2		Min.	7	

Length of life of second-brood pupæ.—Pupal records were obtained from 12 normal pupæ, all males, with one exception, and from 3 parthenogenetic pupæ, and a summary of these records is given in Table XI.

TABLE XI.—*Summary of pupal stage of second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Normal individuals.			Parthenogenetic males.		
Number of individuals.	Days—		Number of individuals.	Days—	
	Each.	Total.		Each.	Total.
2	4	8	1	5	5
6	5	30	2	7	14
3	6	18			
1	8	8			
12		64	3		19
Average		5.3	Average		6.3
Maximum		8	Maximum		7
Minimum		4	Minimum		5

Life cycle and emergence of adults of second generation.—Table XII gives the complete life cycle, from egg deposition to emergence of adult, of 4 parthenogenetic males and 10 normal males of the second generation. The only female of this generation reared to maturity had an abnormal number of molts, and is included elsewhere in this paper.

TABLE XII.—*Length of life cycle of the second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Pathenogenetic males.								
Individual No.	Date of—				Days in—			Total life cycle in days.
	Egg deposition.	Hatching.	Pupa-tion.	Emer-gence.	Egg stage.	Larval stage.	Pupal stage.	
1	June 21	June 26	July 15	July 22	5	19	7	31
2	..do..	..do..	July 16	July 23	5	20	7	32
3	June 30	July 3	.....	Aug. 1	3	.....	.....	32
4	..do..	July 4	July 27	..do..	4	23	5	32
Total.....					17	62	19	127
Average number of days.....					4.2	20.6	6.3	31.7
Maximum life cycle, 32 days; minimum, 31 days.								
Normal males.								
1	June 20	June 26	July 16	July 22	6	20	6	32
2	..do..	..do..	July 18	July 23	6	22	5	33
3	..do..	..do..	July 19	..do..	6	23	4	33
4	June 22	June 28	July 14	July 20	6	16	6	28
5	..do..	..do..	..do..	July 22	6	16	8	30
6	..do..	June 29	July 16	..do..	7	17	6	30
7	..do..	..do..	July 17	..do..	7	18	5	30
8	..do..	June 28	July 19	July 23	6	21	4	31
9	..do..	June 29	July 26	July 31	7	27	5	39
10	June 30	July 3	Aug. 1	Aug. 6	3	29	5	37
Total.....					60	209	54	323
Average number of days.....					6	20.9	5.4	32.3
Maximum life cycle, 39 days; minimum, 28 days.								

Since the complete rearings of this generation were few in number, the average life cycle of normal individuals has been compiled from the figures in Tables IX, X, and XI, and is given in Table XIII.

TABLE XIII.—*Average life cycle of normal individuals of the second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Number of days in—			Total life cycle in days.
Egg stage.	Larval stage.	Pupal stage.	
4.8	21.3	5.3	31.4

Length of life of second-brood adults.—No records were made of the length of life of second-brood adults.

Oviposition of second-brood adults.—Observations were made on a single pair of second-brood adults. The female deposited 34 eggs the first day after she emerged and 40 eggs the second day, making 74 eggs in all.

THIRD GENERATION.

Incubation period of third-brood eggs.—Seventy-four fertile eggs of this brood hatched in 4 to 6 days after being deposited, with an average incubation period of 4.7 days. No parthenogenetic eggs were secured.

Length of life of third-brood larvæ by instars.—Twenty-nine larvæ were reared from fertile eggs, 9 of them pupating, the remainder either dying or burrowing into the earth at maturity and being lost. No parthenogenetic larvæ were reared. Table XIV gives a summary of the length of larval life by instars of all larvæ reared.

TABLE XIV.—Summary of larval life of third generation of the dock false-worm, by instars, Wenatchee, Wash., 1915.

Normal larvæ.																	
First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	1	1	3	1	3	3	1	3	1	1	1	2	2	4	7	4	28
6	2	12	17	2	34	16	2	32	8	2	16	3	3	9	2	5	10
19	3	57	5	3	15	5	3	15	6	3	18	7	4	28			
3	4	12							2	4	8	3	5	15			
29		82	25		52	24		50	1	6	6	15			9		38
Av		2.8	Av		2.1	Av		2.1	18		49	15		56			4.2
Max		4	Max		3	Max		3	Av		2.7	Av		3.7	Max		5
Min		1	Min		1	Min		1	Max		6	Max		5	Min		4
									Min		1	Min		2			

Length of life of third-brood pupæ.—Pupal records were obtained from 9 pupæ of fertile eggs, 4 males and 5 females, and these are given in Table XV.

TABLE XV.—Summary of pupal stage of third generation of the dock false-worm, Wenatchee, Wash., 1915.

Number of individuals.	Days.	
	Each.	Total
4	4	16
4	5	20
1	6	6
9	.....	42
Average	number	of
days	.....	4.7
Maximum	.....	6
Minimum	.....	4

Life cycle and emergence of adults of third generation.—Since all but one of the third-brood larvæ reared to the adult stage came from eggs collected in the field, it is not possible to give a complete life cycle of this generation. Table XVI gives a partial life cycle (omitting the egg stage) of 5 males and 5 females.

TABLE XVI.—*Length of partial life cycle of the third generation of the dock false-worm, Wenatchee, Wash., 1915.*

Males.						
Individual No.	Date of—			Days in—		Total life cycle in days.
	Hatch-ing.	Pupa-tion.	Emer-gence.	Larval stage.	Pupal stage.	
1	July 25	Aug. 12	Aug. 17	18	5	23
2	July 28	Aug. 13	Aug. 18	16	5	21
3	Aug. 1	.....	Aug. 22	.....	.....	21
4	Aug. 17	Sept. 3	Sept. 8	17	5	22
5	..do....	..do....	Sept. 9	17	6	23
Total.....				68	21	110
Average number of days.....				17	5.2	22
Maximum life cycle, 23 days; minimum, 21 days.						
Females.						
1	July 25	Aug. 12	Aug. 17	18	5	23
2	..do....	Aug. 13	..do....	19	4	23
3	July 28	Aug. 14	Aug. 18	17	4	21
4	..do....	Aug. 15	Aug. 19	18	4	22
5	Aug. 11	Aug. 26	Aug. 30	15	4	19
Total.....				87	21	108
Average number of days.....				17.4	4.2	21.6
Maximum life cycle, 23 days; minimum, 19 days.						

As Table XVI is very incomplete, the length of the complete average life cycle has been compiled from separate results obtained for the various stages and is given in Table XVII.

TABLE XVII.—*Average length of complete life cycle of the third generation of the dock false-worm, as compiled from the various stages, Wenatchee, Wash., 1915.*

Number of days in—			Total life cycle in days.
Egg stage.	Larval stage.	Pupal stage.	
4.7	17.6	4.7	27.0

Length of life of third-brood adults.—One male kept with the larval food plant lived 7 days, and two females each lived 5 days.

Oviposition of third-brood adults.—Third-brood females deposited eggs up to 4 days after emerging, the average being 1.9 days, figuring from date of emergence to date of deposition of each egg.

One mated female deposited a total of 133 eggs, and another escaped after depositing 95 eggs. Two single females were observed one of which deposited 83 eggs and the other 104.

FOURTH GENERATION.

Incubation period of fourth-brood eggs.—The length of the fourth-brood egg stage averages a little shorter than that of the second brood, the weather in August being warmer than in June. Records of 174 fertile eggs showed an average incubation period of 3.8 days, and records of 62 parthenogenetic eggs deposited during the same period showed an average of 4.4 days. Table XVIII gives the records for the 174 fertile eggs, and for 157 parthenogenetic eggs, 95 of them being deposited from August 31 to September 4, when the weather was cooler. This makes the total average higher than that of the fertile eggs, as no records of these were secured during this cooler period.

TABLE XVIII.—*Length of the incubation period of fourth-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.*

Fertile eggs.					Parthenogenetic eggs.				
Number of eggs.	Date—		Incubation period.	Total days.	Number of eggs.	Date—		Incubation period.	Total days.
	De- posited.	Hatched.				De- posited.	Hatched.		
1	Aug. 18	Aug. 21	3	3	14	Aug. 20	Aug. 24	4	56
26	...do....	Aug. 22	4	104	12	...do....	Aug. 25	5	60
19	...do....	Aug. 23	5	95	10	Aug. 21	...do....	4	40
41	Aug. 19	Aug. 22	3	123	11	...do....	Aug. 26	5	55
28	...do....	Aug. 23	4	112	8	Aug. 22	...do....	4	32
6	...do....	Aug. 24	5	30	6	...do....	Aug. 27	5	30
1	...do....	Aug. 25	6	6	1	Aug. 23	...do....	4	4
25	Aug. 20	Aug. 24	4	100	1	Aug. 31	Sept. 6	6	6
1	...do....	Aug. 25	5	5	18	...do....	Sept. 7	7	126
1	...do....	Aug. 26	6	6	2	...do....	Sept. 8	8	16
11	Aug. 21	Aug. 24	3	33	2	...do....	Sept. 9	9	18
11	...do....	Aug. 25	4	44	10	Sept. 1	Sept. 7	6	60
3	...do....	Aug. 26	5	15	19	...do....	Sept. 8	7	133
					1	...do....	Sept. 9	8	8
					14	Sept. 2	Sept. 8	6	84
					1	Sept. 3	...do....	5	5
					20	...do....	Sept. 9	6	120
					3	...do....	Sept. 10	7	21
					4	Sept. 4	Sept. 11	7	28
174				676	157				902
Average incubation period.....				3.8	Average incubation period.....				5.7
Maximum.....				6	Maximum.....				9
Minimum.....				3	Minimum.....				4

Length of life of fourth-brood larvæ by instars.—As the fourth-brood larvæ do not pupate the same season, but pass the winter in the larval stage, only the period from hatching to the forming of the pupal or hibernating cell by these larvæ is given in the summary in Table XIX.

TABLE XX.—*Length of partial life cycle of the fourth generation of the dock false-worm, Wenatchee, Wash., 1915—Continued.*

Normal individuals.						
Individual No.	Date of—			Days in—		Average partial life cycle in days.
	Egg deposition.	Hatching.	Forming pupal cell.	Egg stage.	Larval stage.	
1	Aug. 19	Aug. 23	Sept. 18	4	26	30
2	Aug. 20	Aug. 24	...do...	4	25	29
3	...do...	...do...	Sept. 19	4	26	30
4	...do...	Aug. 26	...do...	6	24	30
5	Aug. 21	...do...	Sept. 22	5	27	32
6	...do...	...do...	Oct. 4	5	39	44
7	...do...	Aug. 27	Sept. 24	6	28	34
Total.....				34	195	229
Average number of days.....				4.8	27.8	32.7
Maximum life cycle, 44 days; minimum, 29 days.						

SUMMARY OF LIFE-HISTORY STUDIES.

Table XXI gives a summary of the length of each stage of each generation of the dock false-worm, as worked out at Wenatchee, Wash., in 1915. The column marked "Total life cycle in days" gives the time elapsing between egg deposition and emergence of adult, and the last column gives the time elapsing between the egg deposition of one generation and that of the next. It will be seen that the total of this column (four generations) is 365.6 days, or approximately one year.

TABLE XXI.—*Summary by stages of the length of each generation of normal individuals of the dock false-worm, Wenatchee, Wash., 1915.*

Generation.	Average number of days—				Total life cycle in days.	Average number of days from egg deposition to egg deposition.
	In egg stage.	In larval stage.	In pupal stage.	From emergence to oviposition.		
First.....	10.7	35.6	5.6	1.7	51.9	53.6
Second.....	4.8	21.3	5.3	1.5	31.4	32.9
Third.....	4.7	17.6	4.7	1.9	27.0	28.9
Fourth.....	3.8	233.0	10.5	2.9	247.3	250.2
Total.....	.....	.....	.....	.....	.....	365.6

The seasonal history of the dock false-worm is shown in the diagram in figure 6. In order to avoid crowding, only three points in the life history are shown for each generation, namely, the hatching of the eggs, pupation, and the emergence of the adults. Oviposition would come a day or two later than the adult emergence.

ABNORMAL NUMBER OF LARVAL MOLTS.

We have seen that normally the dock false-worm molts five times, and that consequently there are six instars in the larval stage. It seems certain that occasionally, however, there are seven larval

instars. When this was first suspected several larvæ were being reared on a single plant, and while the molted skin was always removed from the leaf when the record of molting was made, there was some doubt as to whether any of the larvæ actually did pass an extra molt. Subsequently, however, the majority of larvæ were reared singly, that is, only one to a plant, and several apparently

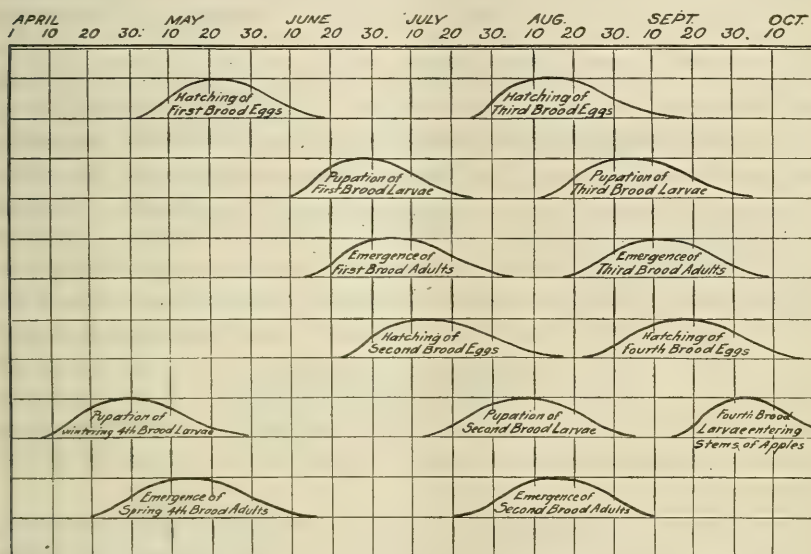


FIG. 6.—The dock false-worm: Diagram illustrating seasonal history. (Original.)

definite records of an extra molt were obtained. These records, while not sufficiently numerous to furnish absolute proof of the occasional occurrence of this additional molt, are given in Table XXII. Individual No. 4 was from an unfertilized egg; the others were from fertile eggs.

TABLE XXII.—Records of larvæ of the dock false-worm having seven instars, Wenatchee, Wash., 1915.

Individual No.	Generation.	Date of—									Sex.
		Hatching.	First molt.	Second molt.	Third molt.	Fourth molt.	Fifth molt.	Sixth molt.	Pupa-tion.	Emer-gence.	
1	1st.	June 29	July 1	July 8	July 11	July 15	July 19	July 26	Aug. 1	.....	♂
2	1st.	July 3	July 5	...do....	...do....	July 14	...do....	July 22	July 29	Aug. 3	♀
3	1st.	...do....	July 7	July 9	...do....	July 13	July 17	July 21	.....	.....	♂
4	1st.	July 4	...do....	...do....	...do....	July 14	...do....	July 19	.....	.....	♂
5	3d.	July 28	July 31	Aug. 2	Aug. 4	Aug. 10	Aug. 12	Aug. 17	Aug. 23	.....	♂
6	3d.	Aug. 4	Aug. 7	Aug. 10	Aug. 11	Aug. 15	Aug. 19	Aug. 23	.....	.....	♂
7	3d.	...do....	...do....	...do....	Aug. 13	...do....	...do....	Aug. 21	.....	.....	♂
8	4th	Aug. 26	Aug. 27	Aug. 29	Sept. 1	Sept. 4	Sept. 9	Sept. 21	.....	.....	♂
9	4th	...do....	Aug. 30	Sept. 9	Sept. 16	Sept. 19	Sept. 21	Oct. 3	.....	.....	♂
10	4th	Aug. 27	Aug. 29	Aug. 31	Sept. 4	Sept. 10	Sept. 16	Sept. 22	.....	.....	♂

RELATION OF TEMPERATURE TO DEVELOPMENT.

Temperature has a very decided influence on the development of insects. Within certain limits increased temperature will hasten development, other factors being equal. The dock false-worm seemed peculiarly susceptible to changes in temperature, and it has already been noted that all stages of its development were shorter in the summer than in the spring. For example, the incubation period of the first-brood eggs (April-May) averaged 10.7 days, while that of the second-brood eggs (June-July) averaged only 4.8 days. Some observations were made on the length of the pupal stage, which, while not taking into consideration the possible effect of differences in humidity and other factors, show very definitely the effect of changes in temperature. The temperature records were obtained from a Richard thermograph placed in the rearing shelter. A sudden rise or fall of temperature hastened or retarded adult emergence. Before April 16 the temperature had only occasionally got above 70° F. From April 16 to 19, inclusive, the daily maximum was above 80° F., and the daily minimum about 50°, whereas it had been about 40° previously. The sawfly pupæ responded to this rise in temperature, and on two days, April 18 and 19, 20 adults emerged from pupæ that had pupated during a period of eight days, or from April 5 to 12, inclusive.

Table XXIII compares the length of the pupal period with the average temperature. This temperature was obtained as follows: The average daily temperature was computed by the sufficiently accurate method of averaging the daily maximum and minimum. Then the average temperature for each individual was obtained by adding the daily averages for the pupal period (including the day of pupation and the day of emergence) of that individual, and dividing by the number of days. The average temperature for a pupal period of any given number of days was then obtained by simply adding the average temperatures of all individuals having a pupal period of that number of days and dividing by the number of individuals. In all, the average temperatures for 137 pupæ of the spring brood and first brood were computed, pupæ from unfertilized eggs not being considered.

TABLE XXIII.—*Length of pupal period of the dock false-worm compared with the average temperature, Wenatchee, Wash., 1915.*

Pupal period in days..	14	13	12	11	10	9	8	7	6	5	4
Average temperature in ° F.....	55.31	55.88	57.65	58.12	58.29	58.62	59.66	61.65	66.60	67.94	70.60
Increase.....		0.57	1.77	0.47	0.17	0.33	1.04	1.99	4.95	1.34	2.66

While no rule can be formulated from the foregoing table, it will be noted that the amount of increase in temperature required to reduce the pupal period one day was greater as the pupal period grew shorter. It required an increase of 3.31° to reduce the pupal period from 14 days to nine days, a reduction of five days, while in order to reduce it from nine days to four days, a further reduction of five days, an increase in temperature of 11.98° was necessary, or over three times as much. The reason for this is evident. It must be remembered that during the pupal stage important changes are taking place. The relatively simple larva is being transformed into the highly complex adult insect. These changes require a certain minimum amount of time, in this case apparently three or four days. On the other hand, there is, at least theoretically, no limit to the maximum amount of time during which the insect may remain in the pupal condition. Hence, as we approach the minimum a greater increase in temperature is necessary in order to produce a given reduction in the length of the pupal period.

NATURAL ENEMIES.

HYMENOPTEROUS PARASITES.

ICHNEUMONIDS.

The overwintering material of the dock false-worm, collected in March, 1915, proved to be rather heavily parasitized. Accordingly a careful record was kept of the parasites, and some knowledge of their life histories was obtained. The parasites emerging were all ichneumonids, and belong to seven distinct species. Mr. R. A. Cushman has examined these and finds them to be *Epiurus pterophorae* Ashm., *Spilocryptus* sp., *Aenoplex* sp., *Bathymetis* sp., *Bathythrix* sp., and two species of *Cratocryptus*. As only three species were recognized at the time of rearing, and the data obtained were rather meager, they are not presented here. It is certain, moreover, that some of these species are secondary parasites. It is hoped that the opportunity will be presented for further investigations in order to work out this problem.

The adults of all these ichneumonid parasites emerge through a hole bored opposite the pupal cell and not through the entrance hole of the false-worm. They are all more active than the adult sawfly. They are all similar in appearance, and not unlike the adult sawflies, being slender and black, with reddish legs. The antennae are longer, however, the abdomen more slender, and the ovipositor of the female is conspicuous. The adults of *Spilocryptus* are further distinguished by a reddish band across the anterior half or two-thirds of the abdomen.

None of these parasites was reared from false-worms that had bored into apples, which indicates that the parasites oviposit in the worms, by means of their stout ovipositors, after the worms have bored into the stems and formed their pupal cells. The parasites would have little opportunity of ovipositing in worms in the apples, even if they could reach them, since the apples are usually picked and hauled away not long after they become infested.

From the infested stems collected in 1915, a total of 261 insects was reared, comprising 92 ichneumonid parasites and 169 sawflies. Thus there was a parasitism of 35.2 per cent.

CHALCIDIDS.

In July and August, 1915, parasitized eggs of the dock false-worm were taken near Wenatchee, Wash. These were black in contrast to the light color of normal eggs. In due time a single small chalcidid emerged from each through a small hole near one end. Specimens submitted to Mr. J. C. Crawford were determined by him to be *Trichogramma minutum* Riley, a minute chalcidid which parasitizes eggs of various Lepidoptera and Hymenoptera, and often practically annihilates its host, at least temporarily. Eggs of the sawfly were collected at intervals from July 26 until September 8, and the amount of parasitism determined. Eggs had been collected several times previous to July 26, but none had been observed to be parasitized. Table XXIV shows the percentage of parasitism.

TABLE XXIV.—Percentage of parasitism of the eggs of the dock false-worm by *Trichogramma minutum*, Wenatchee, Wash., 1915.

Date of observation.	Total number of eggs.	Number parasitized.	Percentage parasitized.
July 26.....	33	13	39.3
Aug. 2.....	15	3	20.0
Aug. 16.....	11	0	0.0
Aug. 23.....	28	2	7.1
Aug. 30.....	158	13	8.2
Sept. 8.....	23	1	4.3
Total.....	268	32	11.9

BRACONIDS.

Kleine (1908) mentions a parasite of the dock false-worm in Germany, which proved to be *Rhysipolis* sp., a braconid.

PREDACIOUS ENEMIES.

Since the dock false-worm is a soft-bodied larva, living unprotected on the leaves of its food plants, it would be reasonable to suppose that predacious enemies in the form of other insects or birds would prey upon it. Only one such case has been noted, however.

On August 12 a chrysopid (lacewing) larva was discovered in the act of devouring one of the false-worms on a plant at the laboratory. The worm was small, having passed its first molt the day before. On August 26 another chrysopid larva was found eating a worm that had hatched August 24. It is probable that ladybird larvæ sometimes also feed upon immature false-worms.

REMEDIAL MEASURES.

Remedial measures may become necessary for the control of the dock false-worm where its food plants are abundant. Thorough and frequent cultivation will keep the plants from growing in orchards where clean cultivation is practiced. The bindweed (*Polygonum convolvulus*), sometimes called black bindweed, is ordinarily classed as a noxious weed, and the other plants are often troublesome and should be kept out of an orchard, even when the false-worm is not present. However, this is not always possible in orchards kept in sod, or where a perennial cover crop, such as alfalfa, is grown. With this in mind, in the fall of 1915 the writer performed a number of experiments in banding trees and in cleaning out the growth of weeds about them, to determine the best method of preventing the full-grown worms from climbing up and getting at the fruit. This work was done in the orchard from which the overwintering larvæ were collected in the spring. It is situated in the Entiat Valley, 20 miles north of Wenatchee, Wash. A portion of the orchard was selected where there was an average infestation of worms on the bindweed. The latter was growing up into the trees in many places, clinging to the trunks and lower limbs. The orchard consisted of Esopus (Spitzenburg) trees, alternating with Jonathans. Only the latter were used, since the year before it was noted that the Jonathans were injured more than the others. Sixteen trees were used, divided into four plats of four trees each. In Plats A, B, and C, the bindweed and alfalfa were cut off near the ground under the trees, and some of the lowest branches were clipped off, leaving no way for the larva to get into the tree except by way of the trunk. A band of a commercial sticky substance, one-eighth inch thick and 3 inches wide, was then applied to the trunks of the trees in Plat A, just below the point where the main limbs branched out. In Plat B, an 8-inch strip of cotton batting was placed about the trunk of each tree and tied on with cord about the middle. The upper half of the cotton band was then rolled down over the cord. Plat C received no treatment aside from clearing out the weeds and clipping a few branches. Plat D was used as a check and was left untouched. This work was done on August 26, as many of the larvæ were found to be approaching maturity. The fruit was picked October 5, and during the interval other work prevented the writer from visiting

this orchard. The owner found it necessary to prop some of the more heavily loaded limbs, and these props were not banded. Some of the lower limbs, too, became so heavy that they were practically lying on the ground. This prevented the bands from forming an absolute protection against the worms, but there was sufficient protection to make a decided difference. The results of the apple counts made on October 5 are given in Table XXV.

TABLE XXV.—*Number and percentage of apples injured by the dock false-worm in the experimental plats, Entiat, Wash., 1915.*

Condition of fruit.	Plat A (commercial sticky substance).					Plat B (cotton).				
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.
Injured.....	7	19	7	4	37	0	2	11	4	17
Sound.....	298	510	628	700	2,136	170	332	466	620	1,588
Total.....	305	529	635	704	2,173	170	334	477	624	1,605
Per cent injured..	2.30	3.59	1.10	0.57	1.70	0.00	0.60	2.30	0.64	1.06

Condition of fruit.	Plat C (weeds cleared).					Plat D (check).				
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.
Injured.....	5	23	14	4	46	25	22	38	22	107
Sound.....	185	535	272	133	1,125	351	531	556	483	1,921
Total.....	190	558	286	137	1,171	376	553	594	505	2,028
Per cent injured..	2.63	4.12	4.90	2.92	3.93	6.65	3.98	6.40	4.36	5.27

This period was almost rainless, and the bands of cotton and commercial sticky substance were in perfect condition on October 5. No difference in effectiveness can be ascribed to the two materials used for bands, the average infestation for the two plats being 1.43 per cent. This is an infestation of only a little over one-fourth that of the check plat. The slightly greater infestation in Plat A (1.70 per cent, as against 1.06 per cent in Plat B) was due to the fact that five props were used in this plat, while only one was used in Plat B, giving the worms more opportunity of reaching the fruit in the former. It was noticed in picking the fruit in these plats that most of the injured apples were on the lower limbs and the limbs that were propped. Practically none were found in the tops of the trees.

The results in Plat C show that merely clearing away the weeds and clipping off the lower branches is of some value, the infestation being about three-fourths that of the check plat. This method may be recommended where banding materials are not at hand.

In general, it may be stated that efficient protection will be secured from the dock false-worm by banding the trees with cotton batting

or other repellent materials safe to the trees, provided the lower limbs are kept well up from the ground and any props used are also banded. The bands should be applied about August 15, and not later than September 1, and under ordinary conditions will remain effective until the fruit is picked. A satisfactory sticky substance may be made by heating 5 pounds of resin until it is melted and then adding 3 pints of castor oil, stirring thoroughly. In using any sticky substance it may be applied directly to the trunks of the larger trees, but if there should be any occasion to use it on trees not more than three or four years old (trees of this age sometimes bear a few apples), a band of paper should first be tightly wrapped about the trunk and the material applied to this, otherwise it may roughen the bark of the tree. Needless to say, this paper band should be removed after the fruit is picked. A band of this substance one-sixteenth inch thick and 3 inches wide is sufficient and will cost about 3 cents a linear foot. The cotton bands are cheaper, costing from 1 to 2 cents a linear foot for bands 6 or 8 inches wide. It takes only a few minutes to apply either material to a tree.

SUMMARY.

The dock false-worm is the larva of a sawfly (*Ametastegia glabrata* Fallén) found all over Europe and in Canada and the northern part of the United States, from the Atlantic to the Pacific.

The larva is a green, wormlike creature, which feeds on dock and related plants; frequently, however, where conditions are favorable, it finds its way at maturity into apple trees, where it bores into the apples to hibernate, making them unsalable.

The dock false-worm has four generations annually, each generation occupying roughly a month, except the fourth, the larvæ of which hibernate and complete their development the following spring. Only the larvæ of this last generation are known to bore into apples.

A number of parasites have been reared, both from the egg and from the full-grown larva, and while these are valuable in partially controlling the false-worm, probably they will never control it absolutely.

Apples may be protected from this insect by keeping the orchard free of dock and other food plants, or, where this is not possible, by banding the trees with cotton or some sticky substance safe to the trees in the latter part of August and leaving the bands on until after the fruit is harvested.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 266

Contribution from Office of Markets and Rural Organization
CHARLES J. BRAND, Chief



Washington, D. C.

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OUTLETS AND METHODS OF SALE FOR SHIPPERS OF FRUITS AND VEGETABLES.¹

By J. W. FISHER, Jr., and J. H. COLLINS, *Assistants in Market Surveys*, and WELLS A. SHERMAN, *Specialist in Market Surveys*.

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INTRODUCTION.

Numerous publications have been issued dealing with the preparation of goods for market, but little definite information has been compiled as to how the commodities are marketed, where to find a market, how to ship, how the grower can protect himself in business dealings, and other questions of vital importance. Farmers are inclined to suspect almost all middlemen of sharp practice, and are especially prone to believe that commission men misrepresent the condition of goods on arrival and render short returns.

Producers are often accused of deliberate dishonesty in their business relations with middlemen because of their failure to live up to agreements in the manner dictated by commercial practice. Yet, in a great majority of cases, the trouble is not caused by intentional dishonesty but rather arises through ignorance of trade condi-

¹ For exposition of distribution methods and charges in the city see Collins, J. H.; Fisher, J. W., jr., and Sherman, Wells A. *Methods of Wholesale Distribution of Fruits and Vegetables on Large Markets* Bul. 267, U. S. Dept. of Agriculture, 1915.

NOTE. This bulletin should be of interest to shippers, dealers, and consumers of fruits and vegetables throughout the United States.

tions and practices, or simply through a lack of the proper commercial perspective. If the grower is to market his products successfully, he must realize the necessity of living up to an agreement and doing business on a businesslike basis. He must learn to ship what he offers, to ship when he promises, and to carry out his part of the agreement even though it means loss.

In a community having the advantages of a cooperative association the burdens and details of marketing are lifted from the producers' shoulders and attended to by experienced sales managers and representatives. In many districts where general farming prevails the formation of cooperative associations may be delayed by the lack of sufficient quantities of any one product. Again there are many sections producing specialized crops where the growers have not taken advantage of their opportunities to cooperate. The information in this bulletin is intended primarily for the independent producer who can not shift the burden of his marketing troubles to a cooperative association.

Cooperation is desirable between grower and grower, and grower and consumer, but it is needed especially between the producer and the distributor. Both must come to understand their interdependence and that best results will be accomplished by working together.

This bulletin attempts to show the available outlets for the individual producer in marketing his fruits and vegetables and how he can get in touch with these outlets. Certain business methods are common in the marketing of all fruit and vegetable crops and an effort has been made here to explain these common points. A glossary of the trade terms used will be found on pages 26 to 28, and as these terms are not used in exactly the same sense in all parts of the country, the glossary should be consulted freely.

FINDING A MARKET.

The necessity for keeping in constant touch with the various markets within his reach is not fully appreciated by the average producer. He realizes the importance of obtaining information concerning production estimates, but does not realize that this is but half the problem. Farm papers are paying more and more attention to market news, and if the readers insist upon more comprehensive service in this respect, the farm journals will emphasize this feature. It may pay in many instances for growers to subscribe for trade papers as well as agricultural journals, for in this way they will learn market conditions from the distributor's viewpoint and the outlook for future market developments. Incidentally they will understand prevailing prices and the opinion of the trade as to the causes of price fluctuations.

If a grower is contemplating a shipment of produce and knows of any other growers in his community who specialize in a large way in this commodity, he usually will find that these men are apt to be well posted as to the markets for this product in the different cities and may be able to give him valuable information. One of the best methods will be to get into personal touch with a reliable representative on the market, for these distributors are willing to give reliable information.

While these remarks apply to both the individual producer and the cooperator, the necessity for information of this nature is not felt so keenly by the latter, inasmuch as the finding of a suitable market is one of the primary functions of a cooperative association.

The constant fluctuations in market prices make it absolutely necessary for the shipper to keep in constant touch with the markets by correspondence or otherwise if he expects to receive full value for his goods. Prices vary widely from day to day, or even in the same day, so that a quotation received from a market representative one day may not hold good for the ensuing day, still less for the ensuing week.

When a grower has his shipments rolling to be sold in transit, the telephone or telegraph must be used if shipments are to be diverted from the point to which they are billed in time to take advantage of a rising market elsewhere.

Before the introduction of day and night letters by the telegraph companies various commercial codes were employed commonly by large distributors. The efficiency of these codes has always been lessened by the liability to error and by the restrictions placed upon their use by the telegraph companies. The inauguration of the day and night letter service by these companies has made the use of commercial codes, to a large extent, unnecessary. Cooperation among producers will do much to distribute the overhead expenses of a comprehensive market news service.

Business convention always demands that telegrams to market representatives be prepaid by the sender, unless the message is in reply to one specifically requesting an answer, or including the words "wire collect."

In general, it appears to be best to sell less-car-lot shipments locally, if possible, and where not possible, to ship to the nearest market on consignment. When shipping in car lots, however, it may pay the shipper to keep in touch with the market in several cities; but a live, progressive firm, upon which the shipper can depend, is a better judge of markets and their conditions than can be the average absentee shipper. However, it should always be borne in mind that he is prone to be prejudiced in favor of his own market.

Many shippers, when writing to distributors, fail to give sufficient information concerning their prospective shipments. The dealers therefore can not give fair quotations on the offered goods. Information can not be too explicit or detailed. Many shippers write that they have a car of apples which will be ready to ship on a certain date. The dealer does not know whether this shipment is in bulk or barrels, nor what varieties, grades, or sizes are to be included. A satisfactory letter to a distributing firm must mention the following points: The probable date of shipment, the commodity, number of packages, kind and size of package, quantity and quality of each variety, whether it is a freight or express shipment, and the road and route. A car-lot shipment seems large to the average farmer who is in the habit of shipping in small quantities, and he may labor under the impression that the dealer will be looking for this one car only, and that, consequently, detailed information as to the time of shipment, and other items, is not essential. On the contrary, this car upon its arrival at the market is but one of many, and may receive no special attention if sufficient information is not given the market representative. Moreover, detailed information often enables the dealer to effect a sale before the arrival of the car.

When he merely writes or telegraphs for prices the shipper must remember not to offer the goods for sale, for, if he does offer them for sale, naming a price, and the dealer writes or telegraphs an acceptance, the contract is legally closed from the time this acceptance is mailed or telegraphed, and the shipper can be held liable in case he breaks the contract. This danger may be avoided by the insertion of the phrase "sale subject to confirmation." A copy of each letter or telegram should be retained by the sender for filing. When writing for prices, the shipper should let the dealers know what and when he expects to ship, inasmuch as they may be able to offer some valuable suggestions.

MARKET QUOTATIONS.

In determining the best market, it is not sufficient merely to get quotations from the different cities and ship to that market which quotes the highest prices. Freight and other charges must be subtracted from these quotations, and, all factors considered, the best market is the market which shows the greatest *net* returns. However, too much dependence must not be placed upon these quotations, as in many cases they are merely approximations or opinions as to the trend of the market and are not usually direct offers. In case of doubt the best plan is to sell in the market with which the shipper is most familiar, through some one familiar with the goods and ways of the shipper.

In finding a market, the quotations or "price currents" will often be of value in determining the general price levels. These quotations

appear in newspapers, trade journals, auction sheets, bulletins published by private commission firms, and farm papers. In the case of fruits and vegetables, they are prepared by newspaper reporters or representatives of trade journals who are supposed to cover the market each morning and determine the range of prices for each commodity, either from actual sales or from the opinions expressed by members of the trade. Public auction sales and transactions on boards of trade also indicate general market conditions and aid in determining prevailing prices for the day. Auction quotations have the advantage of representing actual, bona fide sales in the majority of cases and of showing actual amounts moving at different prices.

Quotations as sometimes published are not of great value unless price ranges are given for the varieties of each commodity as well as for the commodity as a whole. Thus, Northern Spy apples may be selling at prices ranging from \$4 to \$5.50 per barrel, while Ben Davis apples on the same day may be sold wholesale at \$3 to \$4.50. If the published quotations give the range in prices for apples as a whole, entirely disregarding varieties or grades, the quotations in this case would appear as "Apples, barreled, \$3 to \$5.50." This statement would be so broad as to be almost worthless and would lead to serious misinterpretations. The lower figure in the range, as quoted, is supposed to represent the actual selling price for the lower grades. The grower having No. 2 Northern Spy apples to ship, on consulting these quotations might conclude that the market as quoted would be \$2.50 for his No. 2's, whereas sales for No. 2's of this variety actually would bring him \$4. Thus it is evident that unless quotations are given for each variety appearing on the market in any considerable quantity, they may fall far short of giving an accurate index of the market. Another weakness is that while the higher figure in the range as quoted may be \$5.50, very few barrels will be sold at this price, and the prevailing market price for fancy grades of Northern Spies may be as low as \$4.50.

Too often the importance of following the market constantly is not realized, and often quotations will remain unchanged for several days although the market has fluctuated daily. Trade quotations undoubtedly are of great value in determining general price levels and market conditions.

VISITING THE MARKET.

A personal visit to the market which the shipper patronizes will more than repay expenses, for points which seem trivial to him are very important to dealers, and the producer should get the proper market perspective. Such a visit enables the grower to get into personal touch with the distributors, to select a reliable representative, to learn the difficulties under which the car-lot receiver labors, and to appreciate the problem with which he constantly is confronted.

On the market he will see his shipment in competition with the fanciest grades from famous specialized sections. The relative quantity of his pack and grade will immediately be apparent. The selling value of well-known brands and labels will be evident. He will see mixed grades sold at a discount as compared with uniform grades and sizes, and he will note the premium paid for attractive packages and quality. These facts and conditions will be impressed upon him with a vividness which no impression conveyed by any written description can equal.

Railroad officials in the city can be of great help to the producer who visits the market, as they can show him where and how the goods arrive, give him information regarding supplies from various sections at different seasons, from other sections during his own shipping season, and finally put him in touch with trade connections and direct customers. The grower who wishes to understand the machinery which intervenes between himself and the consumer can well afford the time and expense necessary to study the following elements which enter into the distribution of goods in a large city: the railroad facilities for transporting and unloading goods; arrangements for trucking and cartage; cold storage warehouses; kitchens and storages of hotels, restaurants, and clubs; sales methods and handling facilities of auctions, public markets, brokers, car-lot wholesalers, commission merchants, jobbers, grocers, hucksters, peddlers, and fruit-stand men. If possible, it would be profitable to get some prominent dealer to explain in detail how he conducts his business and meets his problems.

BUSINESS RESPONSIBILITY.

When any considerable amount of produce is to be shipped, it will pay to look up a dealer's commercial standing very carefully before shipping in his care. The commercial rating of any dealer may be secured through a number of sources of information. There are several firms which make a business of rating the financial and general credit standing of men in different kinds of business, and which publish reports regularly. These publications are of value and give a general idea as to a dealer's standing, yet, as is perhaps inevitable in such matters, in many specific instances they have been found to be inaccurate. This general credit standing is of prime importance, as a man with a very low financial rating may be one of the very best in honest dealings.

Firm letterheads, giving trade references, should not be accepted at their face value without verification, for it is understood that in some cases firms have made use of the names of banks and other credit institutions without proper authority.

The chambers of commerce, boards of trade, commercial clubs, and similar bodies are often of assistance in giving information as to dealers specializing in different commodities. Local bankers may also be of assistance in determining the responsibility of a particular firm.

Once a satisfactory representative or customer is found, it should be the aim of the shipper to maintain his connection with this one firm, as by so doing mutual confidence will be fostered and better results secured than where the shipper jumps from one connection to another in quest of slightly higher prices. One of the favorite baits of unscrupulous produce firms has been the circulation of quotations slightly higher than the prices actually prevailing on the market. When consignments were made to these houses, it was found that inflated returns had been made for the first few shipments, and then, having established a connection with the shipper and secured his confidence, the price was dropped and the grower was exploited before he awakened to the situation. The trade term for this practice is "overquoting."

PRIMARY OUTLETS FOR PRODUCERS.

It is possible for growers to sell either individually as independent producers or collectively as members of a cooperative association. In either their individual or collective capacities producers may sell direct to the consumer or through existing marketing agencies, popularly termed "distributors" or "middlemen."

Attention is called to the fact that the producers are the primary distributors and that to the extent of their intelligent, effective control over the distribution of their products are they successful in the business side of agriculture. The average farmer has not been alive to the problems attendant upon the distribution of his products, and, in consequence, has left the middleman to perform a service which as a producer he might have performed for himself.

COOPERATIVE ASSOCIATIONS.

Out of real necessity farmers' cooperative associations have been created, and the development of this movement is being increased and improved constantly to meet the growing demands for better service. Cooperative marketing associations are producers' organizations which are organized for the purpose of grading, packing, shipping, and selling products grown by members of the association.

The association takes charge of commodities either at the packing shed or at the shipping station, according to the contracts with members or the custom in the particular community, and usually has full charge of the produce in all sales transactions. Many asso-

ciations sell subject to the confirmation of the grower, but in other instances the grower allows the association to take entire charge of the shipment. It is customary in the sale of citrus and deciduous fruits to pool the returns for definite periods varying from a day, week, or month to the whole season. Pooling means that the returns from all sales by the association within a given period are combined. The returns from each variety and grade are separated, and divided among the members according to the amount, variety, and grade shipped during this period by each grower. Where the product of the association is of standard pack and grade, the method is fair to all concerned.

Some associations make substantial advances to growers either for planting expenses or as an advance on expected returns at the time of shipment, ranging in some cases from 50 to 75 per cent of the expected selling price. Most well-established associations sell direct to the wholesale trade or through salaried representatives or private brokers who are situated in the principal market centers of the country and who, in addition to actually selling the products of the association, keep the central office well informed as to market conditions and prospects. The representatives or brokers in many cases represent the association upon the auction, which is used sometimes in special lines. Some shipments are consigned, although this practice is uncommon with associations in the West, and is being eliminated gradually by nearly all organizations.

The charges for cost of selling range from 2 to 10 per cent of the selling price, the usual charge being 5 per cent. In 1913 the average selling cost of boxed apples by all of the associations in the Pacific Northwest was 7 per cent. This included an assessment for advertising. The usual practice is for the association to announce a certain tax per box or unit to cover the expected selling and other costs. After the sales are made this amount, together with other deductions, such as advances made to growers, is subtracted from the gross proceeds and the balance returned to the growers.

Cooperative organization is more highly developed in the West than elsewhere in the United States. More than 50 per cent of the apples and other deciduous fruits of the Northwest and Middle Rockies and the larger portion of California fruits are distributed and marketed by cooperative organizations of the growers. In the Middle Western, Southern, and Eastern States many special products, such as strawberries, peaches, apples, grapes, onions, potatoes, and other vegetables, are distributed cooperatively in a large way. There are individual organizations that do an annual business in the millions, and it is estimated that the farmers' associations of the United States will transact more than \$1,000,000,000 worth of business in 1915.

This bulletin can not attempt to discuss the functions of these organizations in detail because it is written primarily for the individual grower who has no cooperative organization to handle his shipments for him.¹

SALES DIRECT TO CONSUMERS.

It is a common belief that the most direct outlet for producers, that is, the channel direct to consumers, is always the most simple and elementary of all channels of distribution. It is doubtful whether this is always true, for many difficulties lie in the way of a producer who attempts to get in touch with the final consumers of his commodities. There is no doubt as to the advantages, in that there are no intermediaries in the distribution of these goods and the producer is able to get much higher prices than he could if selling at wholesale.

Before discussing direct methods of marketing it may be well to give some consideration to the difficulties involved, especially in the distribution in the larger cities. In the first place, there is the inconvenience of getting in touch with the consumers who are in the market for the particular commodities concerned and, in the second place, the difficulty of making collections and avoiding bad accounts. The average grower is fully occupied in supervising production on the farm, and it is troublesome enough for him to keep in touch with general market conditions without attempting to handle all of the details necessitated by direct marketing. Finally, these direct channels are possible only in specialized cases where small quantities of goods are to be shipped, and it is seldom that large quantities of products from extensive farms or orchards can be disposed of through these outlets. Wholesale distribution must be resorted to in these cases.

The principal methods of selling direct to consumer by the farmer may be summarized as follows: Direct delivery by wagon or motor truck; sales on public markets; express and parcel-post shipments; peddling from the car doors; and, finally, sales to factories, such as canning or pickling plants, cider mills, and grape-juice factories.

DIRECT DELIVERY BY WAGON.

Direct delivery by wagon or motor truck is practicable only where the farmer lives within a 25-mile radius of the consuming center. Hence this method affords an outlet only for the commodities produced in the area immediately surrounding the market. Such deliveries are limited, in the main, to country towns and smaller cities. The automobile truck undoubtedly is enlarging this radius,

¹ See Bassett, C. E.; Moomaw, C. W., and Kerr, W. H. Cooperative marketing and financing of marketing associations. In Yearbook U. S. Dept. of Agriculture, 1914.

but this service probably will be limited to a very small portion of the total producing area of the country and can not be expected to form an outlet for the great bulk of farm crops. Again, the development of cities with their constant encroachments upon outlying country districts forces production areas farther from the market centers, and in the larger cities makes it practically impossible for growers to deliver their produce direct to consumers. The best examples of successful direct deliveries by growers to consumers are found in the sales of fresh fruits and vegetables in small country towns and in the deliveries of milk from neighboring farms through the residential sections of most of the larger cities.

PUBLIC MARKETS.

Public markets afford a profitable outlet for the farm products of growers located within hauling distance of many large cities. These markets may be either municipally or privately owned. Selling may be either at wholesale or retail, although in many cases both selling methods are allowed. Customarily the sites consist merely of an uncovered tract set aside for this purpose, where space sufficient for the grower's wagon is rented at an average charge ranging from 10 to 25 cents per day. The site may be improved by the erection of sheds or even a specially constructed market house. In the latter instance the interior is portioned into stalls which usually are rented to regular wholesale or retail dealers who buy from the producers.

The grower who sells on the public market has the advantage of being able to ascertain available supplies and thus arrive at a fair market price. He secures the advantage of competitive buying by a large number of dealers who are attracted by a wide variety of products in plentiful supply.

In certain places where municipalities have failed to provide facilities of this character, the growers themselves have organized, purchased tracts of land in the city and developed their own trading place.

Public markets are important factors in the distribution of farm products in many eastern cities, and although they are not quite so usual in the West, they constantly are receiving more attention.¹

EXPRESS AND PARCEL-POST SHIPMENTS.

The extensive use of express and parcel post by farmers in order to reach consumers is of recent development, and the ultimate possibilities of this means of distribution are as yet unknown. The post-office authorities, as well as the express companies, are making efforts to bring the consumer and producer together by publishing lists of

¹ See Branch, G. V. Public retail markets. *In* Yearbook U. S. Dept. of Agriculture, 1914.

producers who have goods to sell, at stated prices, and also by means of lists of consumers who are in the market for different commodities.

The parcel-post shipments up to the present time usually have been limited to shipments of poultry, butter, and eggs,¹ and have been quite successful in these lines. The cost of such service, except for extra fancy stock, in many cases is prohibitive, and it is doubtful to what extent the average farmer can make use of these outlets for miscellaneous products. Without the development of special methods they are not to be considered by those having car-lot quantities.

CAR PEDDLING.

Another method by which the grower can sell direct to the consumer, at least direct to the retail trade, is by accompanying a car of produce to the market and selling direct from the car door to the dealers and consumers. This is termed "car peddling." In order to do this it is necessary in most cities that the producer take out a license from the city authorities which gives him temporary selling privileges. The charge for such a license varies from \$10 to \$25.

While this method of selling may be practicable where the growers have no cooperative association, yet it would be unwise for an individual producer to go on the road in active competition with a competent selling organization. The grower also must bear in mind the fact that although the returns from this method of selling at first may appear large, they will be cut down to a great extent by his expenses, the time consumed, and the consequent neglect of his regular business.

This practice may result also in lowering wholesale prices, inasmuch as the grower may be anxious to get away and may sell at figures which the regular dealers would not accept. Car peddling is more common in the South and Southwest than in other sections of the country.

SALES TO FACTORIES.

Sales to factories may not seem to be rightfully classed with direct sales to consumers. However, when it is remembered that fruit which is taken to a canning factory as a perishable product comes from the factory as a semistaple product, this classification seems reasonable. These factories may be classed under the following general heads: Canning plants, pickling plants, cider mills, evaporating plants, wineries, distilleries, and others of like nature.

Canning plants probably constitute the largest outlet for fruits and vegetables, but there is a common misunderstanding concerning these factories. It is usually understood that these plants utilize the cull grades of fruits and vegetables. This is true in only a

¹ See Flohr, Lewis B. *Shipping Eggs by Parcel Post*. Farmers' Bulletin 504. 1914.

limited way, and the practice is becoming less common. Competition has become so keen among canning factories that quality is now a determining factor of success, consequently they are making an effort to secure the higher grades of fruits and vegetables. It usually is necessary to make contracts in advance if markets are to be secured at these factories. The farmer who approaches the factory only when he has unsalable surplus and the markets are glutted must expect very low offers.

Pickling plants use more vegetables than fruits, and a large part of the cucumber crop is used in this way. Kraut factories, which in many sections afford important markets for cabbage, may be included under this head.

Cider mills and evaporating plants may be said to be the real outlet for cull grades of fruits, although even with these quality is becoming more important. It is a truth too little understood that low grades, while sometimes bringing fair returns, are in reality a detriment to the market, because they tend to pull down the price of the better grades. Farmers will do better on the whole to accept a low price for these cull grades from the factory and keep them off the general market, thus causing the general tone of the market to strengthen materially.

Wineries are most numerous in the western grape sections, especially in certain districts in California. Certain varieties of the European grapes are especially desired for wine manufacture, and the wine industry at Fresno, Cal., is a very important factor in the grape-growing business. The grape-juice factories of New York and Michigan are important factors in the utilization of native grapes in the northern section. These factories are insisting more and more upon a better quality, and cull grapes find a limited outlet. Apples and peaches are the fruits most largely used in the manufacture of brandies and cordials by the distilleries, and these are now insisting upon at least a fair quality.

These industries have become vital necessities in the fruit sections on the Pacific coast and probably will be the determining factors between profit and loss. While the need of such outlets has not been forced upon the attention of eastern fruit growers to the same extent as in the West, nevertheless there is room for much study and development in this field. One of the main principles in successful manufacturing is the utilization of waste materials, and this principle is no less important in fruit growing than in manufacturing enterprises.

SALES THROUGH MIDDLEMEN.

Although direct sales from producers to consumers have their advantages, nevertheless it is true that most car-lot quantities of farm produce must be sold through wholesale distributing agencies,

and the average producer will have to utilize some of the present machinery. There is much misunderstanding and confusion in the use of the terms which designate the different middlemen. In this bulletin an attempt is made to employ these terms according to their most common usage, in order to have definite expressions with which to work.

The middlemen to or through whom growers can sell direct may be enumerated as follows: Country merchants, country collecting agents, country buyers of special products, traveling buyers, private exchanges, operators, brokers, commission men, auctions, and retailers.

SALES TO COUNTRY MERCHANTS.

The primary advantage of dealing with a country merchant is that the farmer can trade with him in person and is more apt to know the financial and moral responsibility of the man to whom he is selling. The country merchant usually will purchase poultry and poultry products, farm butter, wool, hides, or commodities produced on the farm in quantities not sufficiently large to constitute commercial shipments. The farmer is paid for the produce either in cash or with credit at the local store. Provided his purchases are large enough, the country merchant combines them into car lots and sells direct to the city trade, or disposes of them to a car-lot assembler at some neighboring shipping point, who concentrates these small shipments into car-lot quantities, selling to the city trade on his own account; also the country merchant may ship small lots of produce directly to commission houses.

COUNTRY COLLECTING AGENTS.

Country collecting agents, on the other hand, are the country dealers or buyers who go directly to the farm with their wagons, buying or trading for small quantities of eggs, butter, poultry, hogs, calves, and other farm products which they concentrate into carloads and ship to receivers in the city. They pay cash for the goods at the farm. These country collecting agents include the so-called "car-lot assemblers."

LOCAL COUNTRY BUYERS OF SPECIAL PRODUCTS.

Country buyers operate, as a rule, in districts producing large quantities of such specialized commodities as apples, peaches, and citrus fruits. They buy from the producers in car lots and ship to the best available markets, selling on orders or through the usual market channels for whatever margin they can secure. They pay in cash at the shipping point at the time of sale or delivery. This method of sale is common for tomatoes and cantaloupes in Florida, potatoes in Maine, watermelons in Texas, peaches in Georgia and Michigan, and apples in the Eastern States.

The term "country buyers" as used in this bulletin refers to buyers who are permanently located and do not move from one district to another with buying brokers and traveling buyers. In many instances the trade defines this person as a "shipper." Another very erroneous designation is "car-lot assembler."

These local country buyers, where they are well known in particular communities, may prove to be profitable connections for shippers, due to the fact that they have reputations to uphold in order to obtain business, and consequently can not operate on a "fly-by-night" basis. Furthermore, these buyers usually pay cash at time of delivery, and inasmuch as the grower thus has the money in possession, the honesty of the buyer is not so important.

TRAVELING BUYERS AND BROKERS.

Traveling buyers and brokers operating at shipping points work along practically the same lines, moving from one specialized district to another with the advance of the season.

The difference in activities lies in the fact that brokers buy whatever produce is wanted in whatever amounts are desired, and ship to wholesale houses which have placed orders with them, charging a definite brokerage for each car shipped. They are usually "free lances" buying for all who retain them, upon payment of the stipulated brokerage. In reality so-called brokers at the shipping end in addition to buying on orders from wholesale houses also sell for growers and shippers, thus finding outlets for carloads of produce.

Traveling buyers, on the other hand, are employed by single houses on a definite salary basis and perform the services of brokers for these individual houses alone.

In order to attract buyers to a certain section, the first requirement is a crop or crops of sufficient tonnage to make the "deal" of commercial importance. A second requirement is to bring the facts to the attention of the trade before shipments begin. This can be accomplished by advertisements in trade journals or by letters to the largest distributors of these products in neighboring markets, stating the probable number of carloads of each product to be shipped from the district, together with the probable opening date of commercial shipments. Provided a large number of buyers and trade representatives can be assembled, the possibility of higher prices is greatly increased through competitive bidding.

Sales should not be made to representatives of unknown firms without a careful inquiry into the business responsibility of the firms and into the accredited standing of the representatives.

Traveling buyers and brokers will be found in nearly all of the specialized districts as well as in many other sections.

PRIVATE EXCHANGES.

Private exchanges are stock companies, organized for profit, which distribute shipments, usually in car lots, for either individual growers or producers' organizations. They take charge of the goods before they are packed, and sell through salaried representatives or individual brokers in the large markets, subject to the growers' orders. Except that they are operated for profit rather than on a cooperative basis, they resemble very closely the cooperative associations in their distribution and sales methods.

These exchanges charge either a straight brokerage or a percentage based upon contract. The charges vary with each transaction, consequently no general average can be given. In general, their charges will be found to be about the same as private brokerage charges, with an addition sufficient to cover the cost of any extra services which may be rendered. Large quantities of Northwestern apples, Michigan grapes, and California citrus fruits are handled by these exchanges.

OPERATORS.

Operators are large wholesale firms which send private buyers or solicitors into producing sections, and which, through representatives or branch houses in several large markets, afford a wide distribution for commodities purchased on their own account. Some of the firms which have handled a large part of the Colorado cantaloupe production in recent years may be termed operators. These firms performed the following functions: (1) They have advanced rent, irrigation expenses, crate materials, and other supplies; (2) superintended the picking, grading, packing, and loading of the crop; (3) made further cash advances at the time of shipment; (4) distributed the crop.

Operators buy in car lots, and in many cases they will handle the whole "deal" in a particular section, as was done with Colorado and California cantaloupes in the 1914 season. They attend to all of the details of advertising and marketing, and sell the fruit under their own wrappers and labels. The advances made vary with each transaction and depend upon how favorable a contract the grower is able to demand from the representatives of the operators. Cantaloupes in California and Colorado, tomatoes in Florida, and potatoes in Texas are handled, to a large extent, by these organizations.

The producer who sells to operators is reasonably sure of a market, although he may have to accept low prices. The low prices sometimes offered by the firms acting in this capacity are perhaps justified by the fact that they assume large risks and heavy financial burdens, while the growers are relieved of all speculative worries.

CARS BILLED DIRECT TO BROKERS.

A rather uncommon practice is that of the billing of cars direct to brokers in the markets by individual growers. When goods are standardized and the broker can effect a sale, subject to inspection, merely upon notification of shipment, this method may be practicable, but in the majority of cases the average grower will be unable to utilize this method. Brokers handle practically nothing in less than carload quantities, and if it is desirable to ship produce directly to market in less than carload lots, it will be necessary to make use of some commission merchant. Nevertheless, this method is open to any car-lot shipper, provided he meets the requirements of such distributors. Brokerage charges for selling vary from \$5 to \$20 or more a car, depending upon the commodity, the average charge for deciduous fruits being \$15 per car. With oranges, lemons, and grapefruit the average brokerage charge is 5 cents per box.

The advantage to the shipper of using a broker is that the broker is supposedly the representative of the shipper and will look out primarily for his interests. He does not handle any funds and his brokerage is fixed, regardless of the selling price of the goods. He can be of great assistance to the shipper in preventing unwarranted rejections or in securing proper allowances where rejection is justified. In other words, he acts as the personal representative of the shipper on the market.¹

In reality, however, the broker is prone to favor the buyers in order to keep in good standing with the trade. Also, there is a temptation to accept orders for more cars than the market can stand, simply to get the brokerage, with resultant low prices to the growers.

COMMISSION MERCHANTS.

The most common outlet for the producer who is shipping in less than carload quantities is through the commission merchants in large markets. In the larger markets a gradual falling off is noticed in straight commission business. Dealers as a whole prefer the more businesslike method of outright purchases either at point of origin or destination, and lack of standardization and grading is probably the only hindrance to a more rapid reversion to this method of buying. Road salesmen often solicit consignments for their firms in addition to the regular solicitors. Stencils are supplied by most of these companies, giving the address of the firm and a number identifying the shipper, with which the farmer can mark his shipments. When this is done all details of marketing will be attended to by the commission firm. Usually these firms also render account sales to the

¹ For selling methods of the various wholesale agencies on the market, see Bulletin 267, U. S. Dept. of Agriculture.

growers before collection is made, often within 24 hours. In this respect they differ from the broker who customarily makes no collections or remittances to the shipper. In return for this service of immediate remittances and consequent carrying of credit accounts the commission merchants must charge a higher rate than the broker. Because he sells in less than carloads, commission charges vary from 5 to 12 per cent, according to the relative perishability of the goods handled, the average charge on perishables probably being 10 per cent. Commission firms specialize in certain commodities, such as eggs, butter, and cheese, or fruits and vegetables, or poultry and game. Usually each firm will handle any shipments made to it.

AUCTIONS.

A rather uncommon outlet for the individual grower is the auction. Auctions do not openly encourage shipments direct from the producer as they prefer to be impartial sellers rather than receivers of goods. In most cases where goods are so shipped, they are sold unmarked and consequently bring less than commodities marked with well-known brands. Auction charges usually average 2 to 5 per cent for handling the products of cooperative marketing associations. Where these selling charges average less than 5 per cent, a terminal charge of 5 cents a package sometimes is collected from the buyers who patronize the auction.

RETAILERS.

Sales direct to retailers or to hotels and restaurants need no particular explanation at this point. In most cases goods must be of extra fancy quality in order to make it possible to utilize this outlet. Middlemen sometimes perform a great service by repacking and grading products which are sent to them in unmarketable shape or which have deteriorated in transit, for which service a charge must be made. If the farmer desires to save this expense he must perform these services for himself.

GENERAL SALES PRACTICES AND TERMS.

The usual types of sales of produce may be enumerated as follows: Sales at point of origin, sales in transit, and sales at destination. The terms upon which sales may be made may be classified as follows: Cash at farm or orchard, f. o. b. either point of origin or destination, and finally an "on-track" sale for cash at destination.

SALES AT POINT OF ORIGIN.

Sales at point of origin may be either outright sales of commodities before or at harvest, sales on f. o. b. terms, or sales "on joint account."

OUTRIGHT SALE OF GOODS BEFORE OR AT HARVEST.

The outright sale of products before or at harvest does not need much elaboration, as these sales are for cash and the producer can treat in person with the buyer. The only differences that may occur between sales of this class are in the terms. For instance, fruit may be sold to the buyer on the trees, in which case the buyer estimates the probable yield and offers a lump price for the whole crop. In this case the buyer attends to picking, packing, and delivering the fruit, and the grower is relieved of all further responsibility. Many orchardists object to this method of sale, claiming that the pickers and packers hired by the buyer do great damage to the trees while gathering the fruit.

Growers who object to this method of sale pick and pack the fruit themselves, preparing it in marketable shape, and sell the fruit at the orchard. In this case the buyer attends only to loading the fruit on the cars and to its disposition on the market, the grower receiving his money at the time of sale. A variation of this method occurs when the grower sells the crop while on the trees, but payment is deferred until after the fruit is picked, packed, and delivered.

Another common type of outright sales occurs when the buyer contracts to use only fruit of a certain grade, in which case the orchardist must find other outlets for the remaining grades.

SALES ON F. O. B. TERMS.

Sales on f. o. b. terms, due to improved standardization of farm products, are forming a continually increasing portion of the total sales of produce, although the increase is very gradual.

"F. o. b." means "free on board." As sales may be made "f. o. b. point of origin" or "f. o. b. destination," the grower should always be careful to specify whether he means free on board at point of origin or delivered at destination. If the terms of the sale are f. o. b. place of shipment, then the purchaser will have the goods he intends to buy delivered and loaded into the car without any expense to himself. On the other hand if the terms of the shipment read "f. o. b. destination" it means that the freight must be delivered at destination freight paid, or if the freight is not prepaid the purchaser may deduct these charges from the invoice before making remittance.

In fruit and produce circles generally, the term f. o. b. is commonly understood to mean a sale at point of origin, with inspection privileges at destination. These sales are called "f. o. b. destination," "f. o. b. usual terms," or "delivered sales."

Sales on f. o. b. terms may be made either to traveling representatives of distributors or by correspondence with city connections. The former is the most common method of sale for the average eastern shipper who is not handling large quantities of any one type of produce

or who does not enjoy a reputation sufficient to warrant sales on advance orders. An f. o. b. sale to traveling or field representatives of distributors resembles an "on-track sale" at the market center, because inspection is made before the purchase price is agreed upon. Customarily sales are for cash. This method of sale is limited to specialized sections which annually attract many buyers, for competition among several buyers is almost a prerequisite to securing f. o. b. sales. The average speculator will avoid cash f. o. b. sales where possible, but may be forced to buy through keen competition and limited supply. Furthermore, if there are only a few buyers in a certain district, and they know that the growers are more or less dependent upon their offers, combinations may be effected which will result in reducing prices materially. The f. o. b. sale is undoubtedly the most satisfactory for the average grower, for in a majority of cases it is unwise for the producer to attempt to play the market and trust to his own knowledge of market conditions in shifting his car from one larger center to another, excepting as he does so through a cooperative selling organization.

Sales on f. o. b. terms through city representatives, such as brokers or association representatives, or finally, direct to car-lot wholesalers, are made most frequently by cooperative associations in specialized sections. One of the prerequisites is an established reputation on the part of some association which stands back of the products. Comparatively few individual producers ship in large enough quantities to have such an established reputation.

These sales are very rarely for cash; in almost all cases they are in the nature of orders from prospective customers secured by city salesmen or brokers. Salesmen solicit orders for future shipment, instructing the associations or shippers as to the time the goods are desired.

It is customary in making f. o. b. sales to allow inspection by the purchaser at destination. With perishables this is almost a necessity, and there are practically but two reasons why a shipper should refuse inspection at the distribution point—either because he knows that the quality of his goods does not meet the contract specifications, or because he doubts the willingness of the buyer to accept the goods in case of a decline in the market. However, with proper business precautions in selling methods, and with an average amount of honesty on the part of the shipper, neither of these conditions should arise. It is understood that in the case of f. o. b. sales to traveling or field representatives, inspection is made on the track at the time of sale. Under average conditions, inspection must occur, in nearly every instance, at either the point of shipment or delivery.

Certain disadvantages and limitations attend sales on "f. o. b. destination" terms which do not apply to cash f. o. b. sales at point

of origin. One of the most common difficulties is experienced when a buyer orders a car subject to inspection, and, in case of a decline on the market before delivery is made, refuses acceptance because of some alleged deficiency. If a buyer wishes to refuse a car, it is not hard to find some defect which he can use as a plausible pretext for refusal.

This matter of rejection depends entirely upon the nature of the implied contract. If the grower ships a car which is under grade, the receiver has a right to refuse it whether the market is declining or advancing. When a buyer makes a purchase "f. o. b. point of origin" he assumes all risk of loss in transit and must see to all claims for damage. On the other hand, if he buys "f. o. b. destination" or buys "on track" at destination the shipper assumes the risk.

In the absence of special agreement to the contrary, when commodities are delivered to a common carrier for shipment, the title to the goods ordinarily passes to the purchaser when the goods are delivered to the carrier properly tagged and addressed. Usually, discrepancies may be found through which a purchaser can manage to withdraw from his agreement, but where a shipment has been accepted at point of origin it belongs to the purchaser and not to the producer.

Another objection brought against f. o. b. sales is that they will not expand markets to any great extent. In order to expand a market the representative of the selling association or the shipper must have the privilege of making sales on any terms possible, provided the prices are justified by prevailing market conditions, and provided sales are always made subject to confirmation by the shipper.

This question of the relative advantages of sales on f. o. b. terms and sales "on track" at destination is one over which the managers of the large cooperative associations in the country differ greatly. It has been claimed that sales on f. o. b. terms subject to inspection are of no more advantage than sales "on track" at destination, inasmuch as in the majority of cases they must depend upon acceptance at destination. To a certain extent this is true.

On the other hand, advocates of f. o. b. sales claim that when a buyer orders a car on these terms through the city representative of a shipping association, the buyer is really in the market for the supplies ordered. Consequently, when the goods are shipped, there is at least a prospective buyer in sight and the final sale is more likely to be consummated. Even though the market may decline in the interim, the allowance made on account of decline in price is usually not as great as the total drop in the market price. The reason for this is plain. The buyer is in the market for the commodities and he is depending upon this one source to secure them. Although the market has dropped and he naturally hopes for certain

concessions from the seller, yet he will not expect an allowance to cover the total drop, but will be content, in most cases, to compromise and accept a reasonable concession. As a consequence, the selling association will secure larger returns than if it had shipped a car without a previous order, commonly termed a "tramp car," in which case it would have been compelled to accept the prevailing market price.

SALES ON JOINT ACCOUNT.

Sales on joint account are agreements made between the grower or shipper and the market representatives on a certain deal, the latter to contribute his knowledge of marketing conditions and the former to make use of his knowledge of conditions at the producing end. Deals of this kind are possible only where both parties know and understand each other thoroughly, for each is absolutely dependent upon the integrity of the other. The division of expenses and profits varies greatly with each contract, though it may be said that the usual custom is for the net profits, after deduction of expenses, to be divided equally between the shipper and the market representative.

SALES IN TRANSIT.

Customarily sales in transit do not concern the individual grower directly, inasmuch as this type of sale is usually made only by shipping associations. Again, sales in transit are necessary only in the case of large crops of produce which must be kept moving in order to prevent a congestion at the shipping end. In many cases it is impossible for a large association to secure f. o. b. sales for all the produce which it has ready for shipment. Consequently, the manager ships out cars known as tramp cars, which are billed to some diversion point in the general direction of the markets where prices seem to be strongest. While the cars are in transit orders are received and the cars diverted accordingly. In case no buyer is found by the time the diversion point is reached, the car is either diverted to the market which seems to offer the best possibilities or is sent to some auction point.

In these sales either absolute selling power is granted to the representative of the shipping association or sales are made subject to confirmation by the shipper. In the former case, where absolute selling power is granted to the representative, no control is possible by the shipper, inasmuch as the representative becomes the virtual owner of the commodity. Thus a shipper who is unable to keep in close touch with the market may rely on the ability of his representative and telegraph him instructions merely to sell to best advantage. Under instructions of this kind the representative is justified in making almost any disposition of the shipment which he believes to be best.

The usual and safest method is to make all sales subject to confirmation by the shipper and not give absolute selling power to the representative. In this case the broker will offer to the trade or receive orders from the wholesale trade, and if any seem to approximate the market, he will telegraph these offers to the association or shipper. In case the association accepts the offer, the sale is made, usually, with the proviso that the goods are to be subject to inspection by the purchaser.

SALES AT DESTINATION.

Sales at destination may be either for cash "on track," through the auction, or sales out of storage.

TRACK SALES AT DESTINATION AND SALES THROUGH THE AUCTIONS.

Where a car is billed as a tramp car in the general direction in which markets seem strongest and no sale has been made or order secured for the goods en route, the car is diverted to the strongest available market with orders to the local representative or broker to make the most advantageous sale possible. The broker then gets prospective buyers to make inspections and offers, which he submits to the shipper. In case no attractive offers are made the car may be sold through the auction.

SALES OUT OF STORAGE.

Another common procedure for the producer when marketing conditions are not favorable at the time of shipment is to place the goods in cold or common storage until the market strengthens. In this case the shipper becomes a speculator, and usually it is best to allow regular marketing agencies to handle speculative deals, unless the grower has the advantage of a cooperative association and the expert services of a trained manager. In the first place, the average individual shipper has not a sufficient quantity of produce to influence the trend of the market materially, nor is he able to keep in touch with country-wide conditions and probable future developments. In the second place usually he is not able to inspect the goods in storage at regular intervals. The keeping qualities of the same varieties of fruit vary greatly from year to year, and regular inspection is almost a necessity in order that the sales may return a profit. Where growers are cooperatively associated the sales representatives on the different markets can perform this service. As a general principle, it may be stated that only sound and fairly matured stock should go into storage.

In other words, this method of sale is practicable only when the grower can keep in touch with the market, or when he has an absolutely reliable representative on the market who can make inspec-

tions for him and give him expert advice as to the best time to sell. Storage charges in the case of fruits are based upon monthly and seasonal rates. Thus with barreled apples the usual charge is from 10 to 25 cents for the first month, with a monthly charge thereafter of from 10 to 15 cents, or a seasonal charge of 40 to 50 cents, which allows the shipper to store his commodities from one to six months.

In many instances the provision of storage facilities on the farm may be a profitable investment. A storage house or cellar of the simplest type which will hold produce in good condition for even a few days may prove to be a determining factor between profit and loss. For instance, the psychological influence upon a buyer of the realization that the grower is not dependent upon him often will result in the offer of higher prices.

Most growers are unable to store because of the fact that they need immediate cash returns in order to pay existing obligations. Where the standing or credit of a grower or association is unquestioned, it may be possible to secure substantial advances, using warehouse certificates as collateral, but an unknown shipper will find great difficulty in securing such loans. It is doubtful whether advances would be made by banks on warehouse certificates based upon perishable products. Banks sometimes take these certificates as collateral from cooperative organizations, but this is done usually as a matter of form, the bank relying on the warehouse certificates for the perishable products much less than on the assets and general credit of the cooperative organization.

In many cases it also will be necessary to insure the goods while in storage to cover all possible risks, and this is an additional charge which the grower must pay, although comparatively the cost is not great.

CONCLUSION.

The development of the so-called "middleman system" has not been a parasitic growth. Distributors have arisen through economic necessity caused by the ever-widening distance between the producer and the consumer and the ever-increasing demands for service from the latter. There is no doubt that conditions can be improved greatly, but it is no less certain that the distributing trade performs a very valuable service at this time, though sometimes at a tremendous cost and with great waste.

If the suggestions given in this bulletin appear complex, they will at least have accomplished one result—to make both the producer and consumer realize that there is a good reason for the existence of distributors. If the grower is not willing to take all these precautions, assume these risks, and spend the time necessary to locate the final consumer of his goods, he must depend upon the services of

some of these so-called middlemen. Even though the growers may be federated into a cooperative association and thus be relieved of a great many details and dangers, by the employment of an expert sales force, nevertheless the association must in its turn employ at least a part of the present marketing machinery in disposing of the greater portion of its products.

Improvements are needed; of this there is no doubt. Undoubtedly they will be made. However, in the meantime products must be marketed, and until changes are made such marketing machinery as is available must be utilized.

Cooperation will accomplish much in the way of better distribution, the standardization of products, and the improvement of business methods.

SUMMARY.

1. Cooperation is desirable between grower and grower, and grower and consumer, but is needed especially between the producer and the distributor. The grower must realize the necessity of living up to an agreement and doing business on a businesslike basis.

2. The grower should keep in constant touch with the market either through the newspapers, trade papers, private firms, auction reports, or by telephone, telegraph, or mail.

3. In offering goods for sale shippers should give definite and detailed information regarding the prospective shipments, such as the probable date of shipment, the commodity, number of packages, kind and size of package, quantity and quality of each variety, whether freight or express shipment, and the road and route.

4. Market quotations are of value in finding the best market, but only as temporary indicators of general price levels, and too much reliance must not be placed upon them.

5. Personal visits to the market patronized will enable the grower to obtain the proper market perspective. He will see the difficulties under which the distributors work, he will see his products in competition with those from the most highly specialized districts, and he will learn the necessity of good quality, honest packing, and standardization.

6. Before establishing market connections, the dealer's commercial standing should be studied very carefully. Commercial credit agencies, trade papers, chambers of commerce, and local bankers all can be of assistance in this respect.

7. The producer can sell either individually or cooperatively. Cooperative associations assume all marketing responsibilities for the individual shipper and are in a much better position to keep in touch with the market and to secure an equitable distribution.

8. Sales direct to the consumer are not always advisable owing to the difficulties of transportation and the problems of collections

and bad accounts. Direct-to-the-consumer sales are usually possible only with highly specialized commodities of small bulk.

9. Direct-to-consumer sales by the grower may be made as follows: Direct delivery by wagon or motor truck; the use of public markets; express and parcel-post shipments; peddling from the car doors; and sales to factories.

10. Under present methods of distribution most car-lot shipments must be sold through wholesale distributing agencies.

11. Sales to country merchants, country collecting agents, country buyers of special products, and traveling buyers are desirable in that the grower deals with the buyer in person and receives cash at the time of sale.

12. Private exchanges closely parallel cooperative associations in the organization of their sales forces, with salaried representatives or brokers in the larger markets. Thus they are able to secure an advantageous distribution of commodities sold through them. Cooperative associations, however, are mutual organizations of producers, while the exchanges are private companies organized for profit.

13. Brokers and commission merchants are valuable marketing aids to the producer in that they act as his personal representatives on the market. In the case of brokers this is an important consideration in the matter of rejections, for the representative is able, through being on the market, either to prevent rejection entirely or to offer a suitable compromise. Brokers act merely as representatives of the shipper, whereas commission merchants usually have complete authority to dispose of shipments to the best advantage. Brokers handle shipments usually in car lots, while commission merchants handle shipments of any size.

14. The sale of goods before or at harvest time transfers the element of risk from the grower to the buyer and changes the crop into immediately available assets.

15. One advantage of selling goods f. o. b. destination is that although they are liable to rejection in case of damage in transit or a decline in the market, there is at least the prospect of a buyer, and, with reasonable allowances made, the car usually will return a greater profit than if it had been shipped to the market unordered.

16. Provided an order can not be secured by the time a shipment of perishables is loaded, the car can be started in the general direction in which market conditions seem strongest. If a sale is made while the car is in transit, the shipment can be diverted to the proper market.

17. When a car has arrived on the market and is unsold it may be disposed of either for cash "on track," through an auction, or it may be put into storage until conditions warrant its withdrawal.

GLOSSARY OF TRADE TERMS AND EXPRESSIONS AS USED IN THIS BULLETIN.

- Account sales.** The statement which a commission merchant renders to a shipper accounting for the shipper's goods.
- Allowance.** The concession in price made to a buyer in order to induce him to accept a car which he has rejected.
- Auctions.** Organizations, usually in the form of stock companies, whose business is to sell fruits at public sale to the highest bidder, charging a definite fee for this service.
- Brokers.** Agents who negotiate the purchase or sale of goods. They have no financial interest in the goods they handle, and are paid by a definite fee.
- Car-lot assemblers.** A term commonly applied to the country merchants or buyers who purchase in small lots and combine into car-lot quantities.
- Car-lot wholesalers.** Distributors who buy outright fruits and vegetables in car-lot quantities, and who sell to the jobbing or retail trade.
- C. l.** Abbreviation for "car lot."
- Car peddling.** The practice of growers accompanying cars of produce to markets and selling from the car door in the railroad yards.
- Commercial rating.** Extent of financial and general credit responsibility of a firm or individual, as determined by unbiased credit agencies.
- Commission merchant.** A dealer on the market who receives shipments or consignments and sells to the best advantage, remitting the proceeds to the shipper after deducting a specified commission.
- Consignments.** Shipments forwarded or delivered to a representative on the market to be sold or disposed of by him for the account of the shipper.
- Cooperative association.** Mutual organizations of producers formed for the purpose of grading, packing, shipping, and selling products grown by members of the association.
- Country buyers of special products.** Buyers located at central points in districts producing special crops, such as potatoes, who buy on their own account and ship in car-lot quantities.
- Country collecting agents.** Country dealers or buyers who drive from farm to farm buying on their own account small quantities of produce and assembling them into larger units.
- Delivered sales.** Sales in which the terms specify that the goods shall be delivered free of charge at a specified point.
- Distributors.** Individuals, corporations, or associations whose business it is to route, distribute, or market agricultural products.
- Diversion point.** A point at which the carrier will permit the destination of a car to be changed, so located geographically that it is possible for the consignor to change the routing of the car before it reaches this point.
- F. o. b. point of origin.** Indicates that goods must be loaded "free on board" cars at point of origin by the shipper.
- F. o. b. destination.** Indicates that freight to destination must be paid by the shipper.
- F. o. b. usual terms.** Same as "f. o. b. destination."
- Invoice.** A statement sent to a consignee containing a list of the goods which have been shipped to the consignee in question.
- Jobbers.** Dealers at distributing centers who buy usually in less than car-lot quantities from car-lot wholesalers or commission merchants and, in turn, sell to the retail trade.
- L. c. l.** Abbreviation for "Less car-lot" or "Less than car-lot" shipments.
- Margin.** Difference between the buying and selling price.

Middlemen. According to popular usage this term refers to those who share in the profits and losses incident to the handling of goods between the producer and the consumer.

On track. (See "Track sales.")

Operators. Large wholesale firms which send private buyers and solicitors into producing sections and which through representatives or branch houses in several large markets have a wide distribution for goods which they purchase or handle on consignment.

Overquoting. The practice of sending out quotations above the actual market to attract shipments. (See "Quotations.")

Pool. A combination of the returns from all sales by a cooperative association for a given period, each grade and variety by itself, previous to division among the members according to the amount, grade, and variety shipped during this period by each grower.

Price currents. Prevailing market quotations assembled and published daily by private firms or associations of market men.

Private exchanges. Distributing organizations incorporated as stock companies and operated for profit. They distribute shipments chiefly in car lots for either individual shippers' or producers' organizations selling through salaried representatives or brokers.

Quotations. Current prevailing ranges of market prices.

Rolling. A term indicating that a car is on its way to destination.

Sale on joint account. A transaction or some particular undertaking by which two or more parties combine in contributing the necessary capital and services to buy and sell and share the profits or losses resulting therefrom.

Subject to confirmation. A sale not completed until the offer of the buyer is accepted by the shipper.

Terminal charge (auction). A package charge levied on the buyers by some auctions. Supposed to help cover the expenses of opening the sample line for inspection and general expenses of the auction company.

Track sales. Sales made of the goods in the car at point of origin or destination—customarily the latter.

Tramp cars. Cars loaded and shipped without sale or consignment.

Traveling buyers. Salaried representatives of individual wholesale produce houses or distributing agencies who move from district to district, as the season progresses, buying produce for their respective houses.

Warehouse certificates. Receipts issued by storage houses for goods in storage.

Wholesalers. A general and very loose term including practically all those in the distributing trade with the exception of the retailers. (See "Car-lot wholesalers.")

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

- Demurrage Information for Farmers. By G. C. White. Pp. 27. 1915. (Department Bulletin 191.)
- A System of Accounting for Cooperative Fruit Associations. By G. A. Nahstoll and W. H. Kerr. Pp. 25. 1915. (Department Bulletin 225.)
- Strawberry Supply and Distribution in 1914. By Wells A. Sherman, Houston F. Walker, and O. W. Schleussner. Pp. 10. 1915. (Department Bulletin 237.)
- Methods of Wholesale Distribution of Fruits and Vegetables on Large Markets. By J. H. Collins, J. W. Fisher, and Wells A. Sherman. Pp. 28. 1915. (Department Bulletin 267.)
- The Potato as a Truck Crop. By L. C. Corbett. Pp. 24. 1910. (Farmers' Bulletin 407.)
- Storing and Marketing Sweet Potatoes. By H. C. Thompson. Pp. 15. 1913. (Farmers' Bulletin 548.)
- Shipping Eggs by Parcel Post. By Lewis B. Flohr. Pp. 20. 1914. (Farmers' Bulletin 594.)
- Retail Public Markets. By G. V. Branch. Pp. 167-184. (Separate 636 from Yearbook 1914.)
- Cooperative Marketing and Financing of Marketing Associations. By C. E. Bassett, C. W. Moomaw, and W. H. Kerr. Pp. 185-210. (Separate 637 from Yearbook 1914.)

PUBLICATIONS FOR SALE BY SUPERINTENDENT OF DOCUMENTS.

- The Cold Storage of Small Fruits. By S. H. Fulton. Pp. 28, pls. 3. 1907. (Bulletin 108, Bureau of Plant Industry.) Price, 15 cents.
- Cooperation in the Handling and Marketing of Fruit. By G. Harold Powell. Pp. 391-406. (Separate 546 from Yearbook 1910.) Price, 5 cents.
- The Precooling of Fruit. By A. V. Stubenrauch. Pp. 437-448. (Separate 550 from Yearbook 1910.) Price, 5 cents.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 267



Contribution from Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

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METHODS OF WHOLESALE DISTRIBUTION OF FRUITS AND VEGETABLES ON LARGE MARKETS.¹

By J. H. COLLINS and J. W. FISHER, JR., *Scientific Assistants*, and WELLS A. SHERMAN, *Specialist in Market Surveys*.

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INTRODUCTION.

The details of our present system of terminal distribution at large market centers are practically unknown to many producers and consumers. The elaborate commercial machinery whereby fruits and vegetables are brought from distant production areas to our large cities and are there received, divided into smaller lots, and finally passed on to the consumer is an unknown mechanism to the layman. Much confusion and unnecessary explanation could be avoided if those outside the produce trade had a clearer idea of the processes incident to the marketing and distribution of perishable food products. This is especially true in the case of the small shipper. Goods which have reached a large market usually have passed from the producer's control, but the fact remains that an accurate knowledge of

¹ For a discussion of outlets and methods of sale for shippers of fruits and vegetables, see Bul. 266, U. S. Dept. of Agriculture, by Fisher, J. W., Jr.; Collins, J. H., and Sherman, Wells, A.

NOTE: This bulletin should be of interest to shippers, dealers, and consumers of fruits and vegetables throughout the United States.

the means whereby his produce finally reaches the consumer might exert a very appreciable influence on the producer's method of grading, packing, shipping, or selling.

This bulletin is designed to assist the shipper in obtaining a better understanding of prevailing practices and of distributing agencies. This should enable him to use the existing machinery of distribution more intelligently and to avoid certain needless annoyances and losses. Attention is confined to general practices on the larger markets which receive fruits and vegetables in car lots from distant points. The facts are presented in explanatory form and some attempt has been made to give specific advice as to how certain results are to be secured.

A glossary of the trade terms and expressions as used in this bulletin will be found on pages 26 and 27. As these terms are not used in exactly the same sense in all parts of the country, this glossary should be consulted freely.

NECESSITY FOR DISTRIBUTING AGENCIES.

The development of transportation facilities and the extension of our agricultural area have widened the distance between producer and consumer. This is as true commercially as it is physically. This condition has brought with it many difficulties, and the services of specialists have been required to accomplish the distribution of large crops over wide areas. Certain channels of trade have been created and there are numerous avenues through which the farmer may reach the consumer. Few of these avenues are direct. The movement of farm products from producer to consumer appears to both to proceed in most cases along circuitous and devious ways.

This extensive commerce in food products has called into existence many special agencies in that large class known as "middlemen." During recent years there has been a great deal of agitation against those engaged in food distribution. Few people have any clear idea as to just who these middlemen are and what functions they perform. It is probably not going too far to say that, to the uninitiated, the middleman is a rather hazily defined person, whose chief function is to levy, arbitrarily, a heavy tribute on all foodstuffs passing from the producer to the consumer. The attention of the public has been directed to increased costs rather than to service rendered. Evidently it has never occurred to many who clamor for reform that economic conditions would not permit the long continued existence of a marketing agency which was simply a parasite. Sooner or later business competition must eliminate all intermediate agencies which perform no definite useful functions.

Several important factors have contributed to the establishment of many middlemen as necessary agents in the present system of market-

ing. Production during the last decade has increased greatly, and as a natural consequence improved methods and facilities for handling the increase have become necessary. Keeping pace with increased production has come the demand of consumers for more elaborate and efficient service. Little thought is given to the fact that service can become a very expensive luxury. With the widening of the distance between the city and the sources of its fruit and vegetable supplies there has arisen the necessity for special agencies to meet the changed conditions.

The fact should be recognized that present distributive machinery, with all its strong points and its weaknesses, has been created of necessity, and it has weathered the storm of much adverse criticism, because every part of the country is now enjoying the perishable products of the most remote districts. Any readjustment of present market practices must be based upon the fact that some agency must continue to perform the functions of the present-day middleman.

Handling goods through a large market is a very complex process. The problems involved differ greatly from those of production. Usually one man or one firm can not handle both production and distribution and succeed at both. The vast volume of business transacted at large market centers makes necessary some special agencies which can devote all their energies to distribution. Especially does the machinery for efficient marketing become necessary when perishable goods are to be handled. Commodities of this sort must be moved rapidly, must be distributed evenly, and from their very nature permit of no weakness in distributive machinery, if they are to be sold at a profit.

METHODS OF RECEIVING.

As soon as a shipper starts a car of perishables toward the market, he should notify the consignee. This one important detail is often omitted or neglected by shippers. Little thought is given to the fact that the consignee, especially if a large firm, may have many other shipments en route or on hand. The viewpoint of the small shipper whose annual output may be from 1 to 10 carloads is narrowed. The one or two cars which he may be rolling toward market are very important to him, and he usually loses sight of the fact that his property on arrival at the market will be only a very insignificant portion of the total receipts. The firm to which the shipment is made may have more carloads on track and for sale in one day than the shipper would forward in five years.

Keeping records of all these shipments is a great burden on large, wholesale, distributing concerns, and lack of proper notification often causes much needless confusion and costly delay at distributing cen-

ters. A grower who will have one or more cars of produce to market should get in touch with the concern to which he expects to ship his goods some time before they are ready to move. Thus he may secure some valuable suggestions as to packing, loading, or routing the shipment, and these preliminary negotiations will pave the way to a better understanding of terms and the means whereby the produce may be handled rapidly and efficiently. In cases where it is advisable to divert cars in transit or where special preparations must be made to receive and distribute goods immediately, notification of consignee by prepaid telegram should be coincident with shipment. Also, when there is any doubt about a letter reaching the consignee before the car arrives it is important that the wire be used. Telegraphic notifications must make plain just what the shipper has in mind. For instance, a shipper in Florida may consign a car to a commission merchant in Kansas City, and telegraph to him as follows:

Am to-day consigning to you car FGE 16438 containing 330 boxes Bright and Fancy Bright grapefruit; 30 boxes 36's, 100 boxes 46's, balance 54's. Routed via Atlantic Coast Line, Louisville & Nashville, Missouri Pacific. Handle for my account. Letter and bill of lading follow.

The letter which follows should embody the following details: Name of commodity, date of shipment, whether shipped by freight or express, route, car number and initial, number of packages, size and type of packages, variety, and grade.

In case the car is billed to a broker or sales agency the instructions, whether by telegram or letter, should read, "Sale subject to confirmation by shipper," as in this way the shipper has the final word as to the disposition of his property.

Inexperienced shippers may overlook the fact that all railway cars are designated by number and initials painted on the outside of the car. Thus a refrigerator car owned by the Great Northern Railroad Co., No. 51023, would be known as GN 51023. Car 16438, operated by the Fruit Growers' Express, is designated as FGE 16438.

Shortly before the goods reach their destination or immediately after arrival the consignee is notified by the railroad. When highly perishable goods, such as strawberries, are moving, some railroads receive passing reports of cars en route and notify the consignee by telephone several hours before the car arrives, thus giving him opportunity to issue any special instructions or to make arrangements for prompt handling and distribution of the contents on the arrival of the car. In handling fruits and vegetables not so perishable, the railroad, as a rule, notifies the consignee after the car has arrived and confirms this telephone notification by a mailed card, giving car number, initials, and contents.

When no special instructions are given by the consignee many railroads place the cars on their team track soon after arrival in order

that inspection and unloading may be accomplished immediately. When firms have private sidings running into their places of business, it is usual for all cars shipped direct to them to be placed on these sidings without special instructions. Prompt notification by railroads enables the consignees to divert cars to auction sidings without loss of time when it is expected that the contents will be handled through an auction.

INSPECTION.

Soon after arrival it is necessary that an inspection be made. The inspector may be the consignee or his representative. In case the car has been shipped to a broker or a commission man, preliminary inspection is often made by a prospective buyer. If the shipment was made under a "straight" bill of lading, it is necessary that the inspector have a written order issued by the consignee in a form similar to the following:

AGENT, MISSOURI PACIFIC RAILROAD COMPANY,

Kansas City, Missouri.

DEAR SIR: Please permit bearer, John Jones, to inspect the contents of car GN 51023 now on track, consigned to me.

(Signed) J. J. DOE.

Whenever a shipment is billed "Order notify" or "Shipper's order," the bill of lading should be indorsed thus: "Permit inspection without surrender of bill of lading." This will remove the necessity for issuing inspection orders. As a matter of fact, all bills of lading whether "straight" or "order" should read, "Permit inspection," in order to avoid possible complications at destination.

Usually the right of inspection by the purchaser is assured in the case of perishable goods, as it would be very unbusinesslike to purchase or accept a carload of perishables without a careful inspection.

In all cases where the shipper has no market representative he should arrange to have inspection made by disinterested inspectors in case the shipment is rejected.

REJECTIONS.

There are a surprising number of rejections on large markets where great quantities of perishable goods are handled. Few shippers have any idea how large this number is. The facts for one product in one market may illustrate this point.

From the beginning of the shipping season to July 28, 1914, 3 of the 15 railroads touching Kansas City, Mo., brought to that market 227 cars of watermelons. Of this number 47 were rejected

outright and a number of the remainder were reconsigned and subsequently refused at other points. This example does not, of course, indicate normal conditions on this market, nor is this particular distribution center more prone to reject produce than are other similar markets. No exact data as to the causes for these rejections are available and unfortunate conditions may have justified the refusal of any or all of these melons. As a matter of fact, carelessness in grading, packing, and loading are largely responsible for the high percentage of rejections which occurs in the handling of fruits and vegetables. Perishable goods, from their very nature, may be said to invite rejections, and the figures here given are probably indicative of conditions in other distribution centers during periods of market depression.

JUST CAUSES FOR REJECTION.

Satisfactory compromises can be made only where both the shipper and the buyer are broad minded and willing to make reasonable concessions. A very common source of misunderstanding is shrinkage. A shipper who sends fruits or vegetables several hundred miles to market can not understand why his shipment should weigh so much less on arrival than it did at the point of origin. Thus the invoice weight of a car of bulk apples shipped from southwest Missouri on October 16, 1914, was 22,427 pounds. These apples arrived at market on October 23, and were reweighed, barreled, and sold. The weight of the apples at destination was 17,971 pounds, indicating a loss of 4,456 pounds, or 19 per cent, due to shrinkage in transit and to the discarding of a small quantity of culls and spoiled fruit. Very few shippers could be made to believe that a legitimate loss as great as this could occur even though the shipment was graded and loaded carelessly.

An all too common source of trouble between shippers and consignees is nonfulfillment of contract by the shipper. This may furnish just ground for a rejection. Thus, a shipment may be due to leave the point of origin on a certain day, but the actual movement may be postponed by the shipper for several days. A break in the market in the meantime, if the purchaser gives prompt notice to the shipper, will justify him in refusing the shipment when it finally arrives. Again, goods are often not up to the grade specified in the contract. For instance, a grower agrees to ship a carload of fancy, barreled apples. When the car arrives, the purchaser discovers that from 25 to 50 per cent of the shipment is below the standard specified and he very justly refuses the entire shipment or demands a considerable allowance. Often with the best management there remain possibilities for great losses, so that both producers and distributors should

take into consideration the character of the product which is being moved, live up to all agreements, and accept any losses which justly fall to either.

UNJUST REJECTIONS.

A break in the market price may be another cause for rejection and one which can not be justified. A dealer may buy a carload of a certain commodity and certain grade and agree to pay a specified price. Before the car arrives the market price may drop materially. To accept the produce at the contract price may entail considerable loss. Hence, when the car arrives it is given a very rigid inspection, and it is seldom difficult to discover a number of defects in perishable produce when the inspector is devoting close attention to the effort. Thus a drop in market price may convert a car of extra fancy apples into "C-grade" stuff in the opinion of the buyer who sees a loss confronting him.

This practice of rejecting on a declining market is being disapproved more and more by reliable concerns. It injures the business standing of the buyer. One of the worst things that can be said about a produce dealer is that he is a ready rejector. Refusal on a declining market is unfair to everyone concerned. In the case of the buyer, the reputation of a firm may be seriously injured by this practice. In addition, if the buyer is able to effect a compromise with the shipper whereby he is able to secure the produce for a greatly reduced price, he can afford to throw the produce on the market at a price which will depress it still further.

All firms which propose to remain in business are anxious to build up reputations for integrity. All prominent firms have established reputations to maintain and transactions with them are usually safe. Many firms operating on a smaller scale have gilt-edged reputations where they are known and are ambitious to expand their business by giving the best service possible.

Most of the abuses with which the distributing trade in general is charged are traceable directly to the operations of irresponsible dealers, with little financial backing, who do not remain very long in business in any one market. Unjustified rejection is coming to be confined more and more to comparatively unimportant marketing concerns.

REDRESS FOR REJECTIONS.

In case a car is rejected the shipper may sell elsewhere, or may make an allowance on the price to the original purchaser in order to close the transaction. A claim may be entered against the railroad in case the company was at fault in any way. Usually dealers

will accept a car and sell it for what it will bring, and then enter a claim against the railroad through their traffic department in favor of the shipper. When this is done the shipment is accepted from the railroad "under protest," which means that the consignee reserves the right to enter a claim later. Thus, if a car of boxed apples, for instance, should arrive at destination in bad condition, the consignee might give written notice to the railroad of conditional acceptance in some such form as follows:

CHICAGO, ILL., *September 20, 1914.*

Mr. J. J. DOE,

Local Freight Agent, X. Y. & Z. R. R. Co., Chicago, Ill.

DEAR SIR: On September 20, 1914, you notified us of the arrival of car FGE 29853, containing apples. This is to inform you that the contents of this car did not arrive in good order, and we hereby notify you that the receipt of same and payment of freight is made under protest, and claim will be entered for the following reason:

Entire car is badly shifted, causing a number of boxes to be broken and contents spilled on floor. Exact amount of damage can not be determined until car is unloaded.

(Signed)

_____,
Consignee.

There are several essentials to be observed in filing claims. A written notice of the intended claim should be filed with the railroad at once, so as to permit the company to make immediate inspection in order to protect itself. As soon as the exact loss is ascertained by the consignee, claims should be filed in accordance with printed railroad instructions and should offer complete details, backed in every case by affidavits. It is very important that the original bill of lading be in the possession of the party who files the claim, otherwise there may be great difficulty in collecting.

One advantage of handling business through a cooperative organization or other large company is the ease and rapidity with which these concerns can collect just railroad claims. The large associations are in a position to employ trained traffic managers, who, by carefully submitting only those claims which are clearly justified and by backing up those claims with affidavits and evidence, are able to make prompt and full collections.

TERMINAL DISTRIBUTION AND SALES METHODS.

A panoramic view of the activities at one of the large distribution centers of the country would probably reveal some astonishing facts to the layman. When sales are being made on one of our large markets, the mingling of various types of middlemen and the activi-

ties being carried on cause the market to present an appearance peculiar to the produce trade. A great amount is moved by the wholesale trade in the very early morning. At this time, before most of the activities in the city have started, produce distributors find their busiest period. Trucks of fruit and vegetables from freshly "broken" cars are being unloaded on the walk before each business house; ranks of crates, boxes, and baskets nearly block all passageways; and more or less elaborate displays of the day's offerings are being arranged to attract passing buyers. Jobbers, grocers, hucksters, and fruitstand vendors elbow their way through narrow passageways between the tiers of produce, stopping every few feet to inspect goods and ask prices. Street salesmen for each produce firm endeavor to withstand the assault of the throng and each attempts to devote attention to three or four buyers at once. Prices are quoted and violent arguments take place as to quality, pack, and price. After much wrangling and discussion of price and terms, sales are finally made.

Figure 1 shows South Water Street, Chicago, at 8.30 a. m., which is after the rush hours. There is not sufficient light to secure a good picture when the congestion is greatest.

Where a few years ago goods coming to market passed, as a rule, by definite, direct channels to the consumer, to-day the same goods may take any one of a great number of channels, whose directness may or may not be in proportion to the size, type, or quality of the shipment. Large distributing organizations and firms have grown and spread their business activities over much wider fields, but each has worked along its own lines, and each by itself to a certain extent; hence the present lack of uniform practices and systems. In other words, there is no continuous articulation between the different phases of distribution. This does not mean that members of the trade have no common interests. As a matter of fact, their business success depends to a large extent on their ability to secure when needed the help and cooperation of certain of their associates. This community of interests, however, does not obtain among all those engaged in distribution. Distributors are often working at cross-purposes, so that general economy and efficiency are lost in the conflict of interests.

In this discussion rather arbitrary lines are laid down as boundaries for the activities of various types of middlemen, yet in actual practice these activities so overlap and encroach upon each other that resulting market practices are exceedingly complicated.

Goods do not pass in regular order through definite channels, but are sold by any available means. While for purposes of clearness the distinction between the various types of distributing agencies has

been very closely drawn in this bulletin, this distinction is not so apparent in actual practice. One man or one firm may combine the functions of several middlemen. Many distributors act simulta-



FIG. 1.—South Water Street, Chicago, at 8.30 a. m.

neously as car-lot wholesalers, commission men, and jobbers. As a matter of fact, few firms confine their activities to one line of business. Thus, of the goods sold by a firm on one day, part may have

been purchased outright in car lots, part purchased in small lots from other receivers, and part consigned on commission. While one firm may act in the triple capacity of car-lot wholesaler, commission man, and jobber, the three lines of business thus carried on at the same time are very distinct and for purposes of discussion may be considered as being performed by three separate firms. In every large market there are concerns which confine themselves to one of these lines, but by far the greater number of produce distributors do business in several lines.

CAUSES OF COMPLICATED METHODS.

Various factors have contributed to the development of manifold methods of marketing. The use of refrigerator cars for shipping perishables from distant producing sections and the attendant growth of business in handling goods out of season have had a tremendous effect. With the radius of the zone of supplies thus lengthened, marketing activities have increased to keep pace with the movement, and with increased activity have come increases in complexity and in costs.

When consideration is given to the vast territory which supplies any one of our large cities with its fruits and vegetables, the wonder is that distributive machinery is not more hampered and labored in its action. Thus, on one day in the fall of 1914 Kansas City was receiving peaches from Utah, Idaho, and Washington; grapes from California and Michigan; cantaloupes from Colorado, New Mexico, Arkansas, and Missouri; pears from California and Colorado; sweet potatoes from Virginia and Georgia; and apples from Colorado, Washington, New Mexico, New York, Arkansas, and Missouri. With daily supplies coming from all sections of the country and with the necessity for adjusting machinery to care for varying quantities, it is not to be expected that the flow of produce through market channels will be smooth and uninterrupted, nor that prices will be stable and uniformly satisfactory.

SALES BY BROKERS.

In spite of general complexity, however, explanations of the sales methods of some of the principal, independent, distributing agencies may prove useful. Thus, there is the broker who handles car lots only, as a rule, and who draws his business from cooperative associations, country speculators, large operators, private exchanges, and in some cases private shippers. According to strict interpretation, the term "broker" can be applied only to those middlemen who act as intermediaries between the principals in contemplated transactions and have nothing further to do with the contract itself. The broker normally does not have possession of the articles he deals in,

but must carry on all business in the name of his principal. Commodities handled by brokers, as a rule, are sold to car-lot wholesalers or jobbers.

At the beginning of each business day the broker looks over his business, ascertains conditions on other markets, and takes note of the number of cars he has on hand, number en route, etc. With all this well in mind, he is ready to approach the wholesale trade. His next step is to make a careful canvass of the wholesale district, visiting or calling up by telephone all those who may be interested in what he has to offer. When a possible customer is found, the next step, in case the car or cars have arrived, is to allow the prospective buyer to inspect the contents. After inspection, satisfactory terms are arranged and then before the sale can be consummated it is necessary that the shipper confirm the broker's action. Assuming that the broker is selling a car of apples, Ganos and Grimes for instance, he may telegraph the shipper as follows:

Jones offers on car MC sixteen eight fifty-four, two fifty Ganos, two seventy-five Grimes, delivered.

In case this offer is satisfactory, the shipper's reply may read:

Confirm car MC sixteen eight fifty-four Jones, two fifty Ganos, two seventy-five Grimes, delivered.

Or in case the price is unsatisfactory, the shipper might refuse as follows:

Jones too low; car MC sixteen eight fifty-four; must have three Grimes.

Collection is often made through a bank located at destination. The shipper sends the bill of lading with draft attached to a bank, at the time the car is shipped, and after inspection the purchaser pays the draft and secures the bill of lading. Some large shipping organizations whose responsibility is well known to railroad officials often temporarily retain possession of the original bill of lading and effect delivery by a signed delivery order somewhat as follows:

KANSAS CITY, Mo., *September 21, 1914.*

AGENT, MISSOURI PACIFIC RAILROAD CO.

DEAR SIR: Please deliver on this order without bill of lading car of apples C. B. & Q. 36066 to John Jones, Kansas City. We pay all charges.

The bill of lading is retained temporarily in this case, as evidence of former ownership, or for use in case a dispute should arise later or claim be entered. It is absolutely necessary to insert the clause "We pay all charges," as in many cases railroads will refuse such delivery unless it is understood definitely which party pays the freight.

BROKER'S SETTLEMENTS.

Sales by brokers are, as a rule, strictly cash transactions and collection is made when delivery is offered. All cartage expenses in get-

ting the goods from the car to the dealers' place of business are paid by the buyer. In case the broker did not make a direct sale, but handled the goods through auction, his activities would be confined to seeing that the goods arrived at the auction and attending the sale to withdraw the shipment if prices were unsatisfactory.

BROKER'S EXPENSES.

The broker perhaps handles more business at less cost to himself than any other type of middleman. He has no considerable amount of capital in his business and a large part of his expenses is practically fixed. His heaviest items of expense are usually rent, clerical help, and telegraph charges. The latter, of course, varies with the amount of business handled. As a rule, most of the broker's business is composed of association accounts and accounts of large private shippers, and a very small portion is drawn from small shippers. The broker acts as the exclusive agent on his market for each concern that he represents, and since he handles car lots only and moves large quantities in relatively short periods of time he is enabled to render important services at a very low cost to the shipper.

BROKER'S ABUSES.

Brokers are often charged with misuse of their privileges in that they may sometimes speculate on goods passing through their hands. For instance, a broker may make returns out of his own funds for a supposed sale, but hold the produce for a rising market before actual sale is made. If the expected advance occurs, he pockets the increase in price. This practice would prevent a shipper from getting just returns and his goods would not be on an actively competitive basis with other market offerings. In other words, such sales would secure to the grower or shipper the lowest market price quoted on the day returns were made and he would get no benefit from either the expected rise in price or the broker's ability as a salesman. This tendency toward speculation is ordinarily done away with entirely when there is direct dealing between the vendor and vendee, so far as the handling of money is concerned. As a matter of fact, according to a strict interpretation of the term, the shipper's selling agent ceases to be a broker when he assumes responsibility for collecting and remitting, and so the term "broker" as here used is applied according to trade usage and common understanding. Brokers are charged sometimes with failing truly to represent the shipper. Being always in close personal touch with buyers and having no such close relation to the shipper, there is sometimes the tendency to favor the buyer unduly in order to retain his good will.

THE BROKER'S PLACE IN DISTRIBUTION.

Brokers act as market salesmen for those producers who are unable to make direct sales and who have no other market representative. They represent shippers at large distribution centers, and by the payment of the very small brokerage fee the shipper can be certain that his goods will be accepted on arrival. The broker, by making prompt disposition of a consignment immediately upon arrival, often saves the shipper many times the brokerage fee. Brokers stimulate and expand the market to a certain extent by their expert canvassing of the trade and any influence that stimulates active buying and selling must be regarded favorably. In general, their chief usefulness lies in the fact that their activities on the market tend to maintain a steady flow of business.

AUCTION SALES.

Auction companies are organizations (usually incorporated as stock companies) which sell fruits at public sale to the highest bidder. The auction offers an outlet for a great deal of produce that can not find immediate, direct sale. Those who sell through an auction may be brokers (representing shippers and associations), speculators, operators, car-lot wholesalers, and in rare cases individual shippers. Sales are made largely to jobbers. Before sales are started a display is made in the showrooms. Produce to be sold is divided into "lines" which consist of from 1 to 100 or more packages. Each line is marked with a designating number and listed in definite order on the various sheets which make up the "catalogue." Before bidding starts buyers who are interested in the day's offerings make careful inspection of the various lines and make notes on the catalogue as to comparative values. By the time of the opening of a sale each buyer has a pretty definite idea of the value of the various lines in which he is interested.

Sales start at a definite hour and are conducted much as other auction sales are handled. Bids are started at a fairly low figure and the final price received is dependent to a large extent on the size of the day's offerings and the activity of the bidding. After other offerings have been disposed of miscellaneous broken packages are sold. As sales are made prices are listed opposite the number of the line on the catalogue. A complete catalogue with the prices received for the goods listed opposite the lines is known as a "realizer." Sales are supposed to be strictly for cash, and since, as a rule, single lines are not of any great size the amounts due in each case are not very large.

AUCTION CHARGES.

Auction service charges are from 2 to 15 per cent (usually 3 per cent) on gross selling price. Where the selling charge is under 5 per cent a "terminal charge" to cover costs of unloading and handling is sometimes added. This terminal charge is paid by the buyers and is simply a means for securing increased revenue, since business reasons make it necessary for certain auctions to handle goods on a very low selling charge, and some additional income is needed to offset the costs of doing business. Since the auction itself operates strictly on a nonspeculative basis its costs are fixed, in a measure, and as a rule consist of such charges as rental, interest on investment, and employment of help.

AUCTION ABUSES.

One weakness of auctions lies in the possibility of manipulating the sales so that goods sold on certain days will not move at true market prices. In some cases members of the distributing trade in certain cities may be interested financially in the local auction. In such cases it is possible that the business will be conducted so as to favor those who are supporting the auction. Thus, those who are interested financially may secure more or less extended credit, while all others must deal on a strictly cash basis. This, of course, would give an immense advantage to those especially favored and tend to create dissatisfaction among the greater number of buyers.

Another weakness lies in the possibility of tampering with sample boxes in particular lines. However, in justice to the many reputable auctions operating in different parts of the country, it should be said that there is little evidence that any of the abuses mentioned affects the great volume of business handled daily by them.

ADVANTAGES OF THE AUCTION.

Auctions offer quick outlets for fruits which must be kept moving in a more or less steady stream from producer to consumer. Large quantities of citrus fruits are sold at auction on several of our large markets. When this fruit starts toward market there arises the necessity for keeping a steady stream flowing to the consuming public, and the auction provides one means whereby distributing channels are continuously supplied. Auctions offer an outlet for surplus holdings on well-stocked markets, and, by attracting buyers, tend to expand the market to a certain extent. They afford a good index of market conditions, and when the auction company sells the major part of the supply of certain commodities or is patronized by most of the buyers, it tends to be a more or less accurate determiner of basic wholesale prices.

CAR-LOT WHOLESALERS.

A very important factor in market distribution is the car-lot wholesaler. These men purchase fruits and vegetables from cooperative associations, country merchants, car-lot assemblers, traveling buyers, buying brokers, individual growers, speculators, and city brokers. They distribute goods to the jobbing and retail trade or to the country trade. Thus it will be seen that their activities cover a wider field than do those of almost any other type of distributor.

A large part of the business done by the car-lot wholesaler is transacted very early in the day. Most of these early morning sidewalk sales are for cash, and in a great many cases the buyer does his own delivering. Later in the day, beginning about 8 or 9 o'clock in the morning, telephone orders come in from grocers all over the city for deliveries to be made later in the day. The greater portion of this business is for credit, but settlement is usually demanded within a period of one or two weeks. Still later in the day shipments are made up for distribution to country customers in neighboring towns. Thirty to sixty days' credit is extended to these customers. The orders from this country trade may be by telegram, by letter, or through private traveling salesmen. As a rule, these sales to the country trade are the most uniformly profitable of any to the car-lot wholesaler. Prices charged are usually slightly higher than can be secured from resident buyers on the market. This, of course, is justified, as extra packing and cartage charges are involved. The country trade, as a rule, makes little attempt to keep in close touch with market prices, but prefers to place orders regularly with selected wholesalers or jobbers and depend upon receiving fair treatment.

In addition to selling to the retail trade, popularly known as "retailing," car-lot wholesalers distribute considerable quantities of goods to jobbers. The "jobbing price," it should be noted, is usually less than prices charged the retail trade for the same articles. This lower jobbing price is, of course, to protect the jobber and insure him at least a small margin or profit when he, in turn, sells to the retailer.

SALES OUT OF STORAGE AND CLEAN-UP SALES.

Many car-lot wholesalers buy when prices are cheap and put the produce in storage, distributing later when prices admit of a fair profit. This involves a certain element of risk, as a market may not take on a better tone in time for the wholesaler to move his stored goods to advantage. Some of the heaviest losses in the wholesale trade are the direct result of dealing in stored goods.

After a heavy day's sale there is usually a considerable amount of miscellaneous produce left on hand. At this point hucksters and peddlers purchase the odds and ends that are unsold and clear the

market for the next day's offerings. These sales are to be commended, as considerable quantities of low-grade stuff are thus placed within the reach of the consumer at reasonable rates, and the practice serves to rid the market of a surplus of low-grade produce.

COSTS AND PROFITS.

Profits to the car-lot wholesaler vary greatly. Since he deals very largely in perishables in large quantities and on his own account, his aim is to make as much profit as possible on each sale. He has better chances to make wide margins than has the jobber, because in many instances he deals directly with the farmer, who is an inexperienced seller and unfamiliar with market methods. However, the car-lot wholesaler buys in large quantities for future sale and thus takes greater risks than the jobber, who buys in small quantities from day to day, moves goods rapidly, and in cases of sharp market declines is able to close out very quickly.

Average net profits at this step in distribution are usually less than is popularly supposed. For instance, during the fall of 1914 apples were handled in Chicago and Kansas City on a gross margin of 25 cents a barrel, oranges at 10 and 15 cents a box, and lemons at 25 cents a box. The margin of profit varies greatly on individual sales and ranges from less than nothing to 50 per cent. Business competition is usually very keen and prevents any long-continued, excessive margin or profit. The car-lot wholesaler's business is subject to all overhead fixed charges, such as interest on investment, labor, and rentals, and in addition he is subject to the costs of much extra service, such as resorting, repacking, and the making of special deliveries. Considering his costs of doing business and the services which he renders, the car-lot wholesaler probably operates on as small a margin of profit as any middleman concerned in food distribution.

FUNCTIONS PERFORMED BY CAR-LOT WHOLESALERS.

These men perform the absolutely essential functions of acting as primary distributors of produce arriving at market in car lots. Any reforms which may be accomplished in distributive methods must take into consideration the fact that some definite agency must undertake the work of breaking car lots and starting distribution at market centers. Hence, the car-lot wholesaler is undoubtedly a highly important element in present-day distributing machinery.

SALES THROUGH COMMISSION MERCHANTS.

The commission merchant is a professional agent whose business is the selling of goods on commission. He has possession of the

commodities, and all transactions are in his own name. He may dictate terms and methods of sale, but must obey instructions if given, and he is responsible to the shipper only for a proper accounting in the final terms.

Commission men solicit shipments from growers, car-lot assemblers, and cooperative associations. It should be stated, however, that cooperative associations do not favor the promiscuous consignment of their products and seek to eliminate this method as far as possible. Consigning is a very common means for disposing of less than car-lot shipments and offers practically the only means for disposing of poor, unstandardized products which could find no direct sale to the wholesale trade. Commission merchants handle goods for 5 to 10 per cent of the gross selling price. In many cases, however, the dealer, by sharp practices, increases his margin to 15 per cent or over. As sales are made he presumably keeps a careful record of each man's transactions, but may or may not give the consignor this detailed information as to the distribution of the shipment. As soon as the shipment is "closed out" the commission man deducts freight and other expenses and his charges and remits the balance to the shipper, together with an "account sales." Costs of doing business are much the same as for the car-lot receiver.

ABUSES BY COMMISSION MERCHANTS.

One charge made against dealers of this type is that they sometimes remit more than the market price to a new shipper in order to get future business. As this does not give the shipper a fair idea of the market and does give him a false impression of the dealer's ability as a salesman, it is a practice which should be regarded with great disfavor by all interests in the market. Another malpractice sometimes attributed to commission merchants is selling for more than the market price and remitting to the shipper on the basis of the market price. Many have regarded this practice as legitimate, because the increased selling price is not due to the superior quality of the goods sold but to the dealer's excellent salesmanship. These practices certainly are not common to most commission men and are not universal, as is generally supposed. Much that the shipper considers dishonest can be explained, his suspicions being due to misunderstanding, or the trouble may be traceable to the shipper himself.

The commission merchant occupies a rather difficult position with respect to his dealings with shippers and shipping associations. The handling of large quantities of fruits and vegetables involves a greater opportunity for mutual misunderstanding than almost any other line of business. The very facts that the commission merchant assumes complete charge of goods intrusted to him, that distribution

is effected according to the commission man's own ideas, and that the shipper's returns are in direct proportion to the dealer's honesty and ability, all tend to encourage a suspicious attitude on the part of the producer. It is not because commission men as a class have proven to be dishonest, but the very fact that the commission man has great opportunities for dishonesty, if he chooses to avail himself of them, has caused shippers to condemn unhesitatingly any practices which did not appear to be perfectly plain.

A shipper is seldom able to inspect his own output with an unprejudiced eye. The car which he is shipping usually appears better to him than does his neighbor's offering. The buyers with whom the commission merchant must deal, however, have no such biased viewpoint. The shipper's goods are compared critically with competing offerings from many sections and quality and pack are the sole deciding factors which determine relative values. Often, therefore, the shipper who considers his goods on a par with the best market offerings is disappointed when returns are below the figures listed on current wholesale quotations. The dealer, who may have exerted every effort on behalf of his shipper, is then accused of dishonesty in that returns were not up to expectations.

Often, too, perishables which leave the point of origin in first-class shape arrive at destination in a greatly deteriorated condition, must be repacked or regraded by the commission men, and finally sold at a considerable loss to the shipper. The grower, who last saw his produce in first-class marketable condition, does not understand or appreciate the conditions which were responsible for this loss.

In general, it may be said that a large part of the stigma which attaches to the business of the commission merchant arises directly from the difficult position which this middleman occupies in distributive machinery.

PLACE OF THE COMMISSION MERCHANT IN DISTRIBUTION

Commission houses offer almost the only good outlet for unstandardized goods which can not be sold direct to the wholesale trade. Acting as primary receivers of less than car-lot shipments, they serve as a medium through which to market all goods which can not be sold direct to car-lot wholesalers, and, when honest and efficient, they offer to inexperienced shippers the valuable services of trained market experts in disposing of their produce.

JOBBER'S SALES.

Next in importance to car-lot wholesalers on large markets is the jobbing trade. Jobbers are middlemen at distributing centers who usually buy in less-car-lot quantities from car-lot wholesalers or

commission men and in turn sell to the retail trade; in other words, they are intermediaries between primary receivers and retailers. The term as here used must be distinguished from the term "jobber" as used in connection with wholesale distribution for manufacturing concerns, where the jobber distributes the total output of several factories direct to large wholesale houses.

Jobbers in fruits and vegetables get their supplies from commission merchants, car-lot wholesalers, auctions, and public markets, and in turn sell to the retailer or to other jobbers. The chief outlet for the jobber, however, is the retailer. Methods of sale by jobbers and car-lot wholesalers are practically identical. The jobber, acting as the intermediary between the car-lot wholesaler and the retailer, buys in less than car lots, as a rule, makes quick sales, operates on a relatively small margin, and secures his profits by rapidly turning over his capital.

In general, the jobber is subject to much the same charges and costs of doing business as the car-lot wholesaler. Often, however, these costs are relatively less in proportion to the quantity of produce handled. The jobber usually has a smaller initial investment than the car-lot wholesaler, hence his general expenses may not run quite so high.

THE JOBBER'S PLACE IN DISTRIBUTION.

The jobber's chief usefulness at the present time is in facilitating the rapid distribution of extremely perishable products. A car of strawberries, for instance, will usually be disposed of much more rapidly when handled by several jobbers than would be the case if a single car-lot wholesaler attempted to complete the distribution to the retail trade. With the growth of standardization, better grading and packing, together with greater efficiency in the business of car-lot receivers, it is possible that many of the present functions of the jobber may be assumed by the car-lot wholesaler. This applies to our smaller markets especially. On the great terminal markets, however, the jobbers must remain important factors for some time to come. In these cities they sell to the vast number of those retailers who buy in small quantities and who can not take time or trouble to go to primary markets and select their goods.

If the entire retail trade were to attempt to get in direct touch with car-lot wholesalers on our large markets, the congestion of business would be so great as to block most seriously the economical movement of perishable food products.

PUBLIC MARKETS.

Public markets draw a considerable portion of their supplies from producers in neighboring districts. They are patronized by

jobbers, retailers, and consumers and enable some produce to pass directly from the grower to the consumer. As a rule they are not highly important factors in the distribution of perishables arriving in car lots from distant production areas. During late years more and more attention has been directed toward extending the usefulness of this form of distribution.¹

DISTRIBUTION CHANNELS.

The foregoing discussions indicate in a general way the great complexity which attends the distribution of food products. The impression may have been left, however, that all perishables pass through each of the steps in distribution which have been noted. This is not the case, as various factors decide what channels each shipment is to take. A complete discussion of the various means by which produce is collected, concentrated at market centers, and finally distributed to consumers is impracticable in a publication of this kind. Perhaps the subject can be made more clear by graphic representation of the more common steps in distribution.

In figure 2 the interlocking circles are intended to show the intimate relationship existing between certain of the agencies interested in distribution. Thus the grower may operate individually or he may combine with his neighbors and all do business collectively or through a cooperative organization. On the other hand, one firm often performs the functions of the car-lot wholesaler, the commission merchant, and the jobber, and the business details overlap in such a way that it is difficult to dissociate the three lines of business. In a single diagram of this kind it is impossible to indicate all the possibilities. Attention has been confined, therefore, to primary distributing channels.

An attempt has been made to emphasize the routes through which the great bulk of traffic passes. Perishables do not and can not pass through the hands of all the distributing agencies which are indicated. As a matter of fact, usually only a few agencies are instrumental in handling the contents of any given car. The contents of two cars coming to a large market on the same day may pass into consumption through very different channels. Thus one car may be consigned to a commission merchant, who divides the car among a large number of jobbers and retailers, while the other car may be purchased by a buyer for a car-lot wholesaler who sells to the jobbing and retail trade. In either case the retailer is the intermediary with whom the consumer comes in contact.

¹ For a discussion of the place and needs of city markets, see "Retail Public Markets," by G. V. Branch, Yearbook U. S. Dept. of Agriculture, 1914, pp. 167-184. (Y. B. Separate 636.)

There are usually very definite reasons why goods coming to market pass on to consumption through such diverse channels. Among those factors which decide along what course and through what hands perishables shall pass in going from producer to consumer are: (1) The condition or tone of the market; (2) grade, pack, and quality of the shipment; (3) district in which the ship-

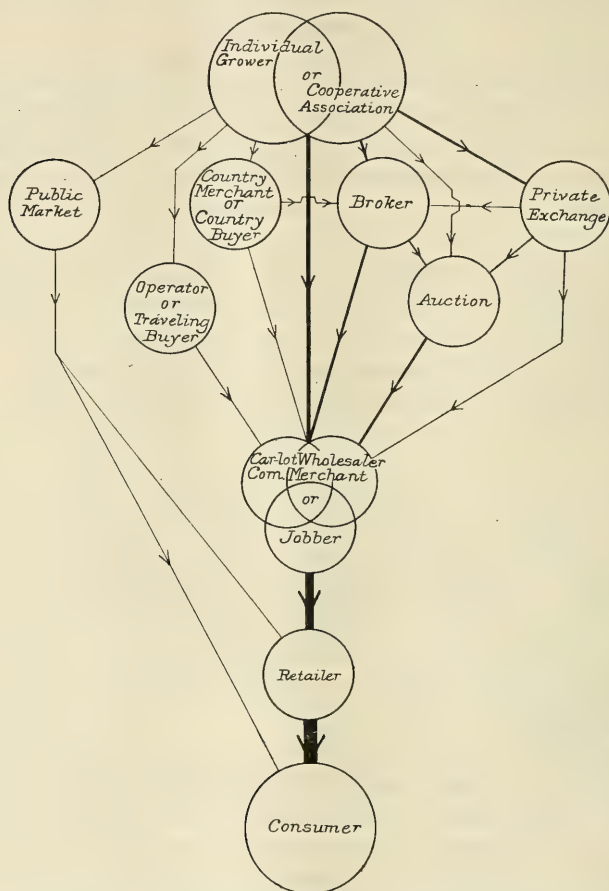


FIG. 2.—Main channels of distribution for fruits and vegetables.

ment originates; and (4) the shipper's knowledge of market conditions.

As a rule, certain types of distributors handle most of the produce coming to market. One principal line of distribution is from grower to car-lot wholesaler, to jobber, to retailer, to consumer. Goods consigned on commission may pass from grower to commission man, to retailer, to consumer. The car-lot wholesaler, commission merchant, jobber, and retailer are highly important market factors,

and collectively handle the great bulk of all perishable food products coming into the city. The diagram (fig. 2) is not intended as either a justification or a condemnation of present market practices but rather to portray distributing machinery, its importance, and the relation of its several parts in the present scheme of marketing.

LOSSES AND WASTES.

Losses and wastes due to deterioration of goods are heavier than is usually believed, and especially is this true in the case of perishables. On such commodities as strawberries, peaches, and grapes the losses sometimes amount to 30 or 40 per cent of the whole. Out of one car of bulk Ben Davis apples from the Ozarks which went to a large neighboring market 19 per cent was lost before the fruit reached the hands of the retail trade. Losses due to spoiling may be the result of the shipper's sending overripe or diseased fruit, or failing to give proper attention to packing, to loading, or to bracing the packages in the car. Sometimes the railroad is at fault. Delay in transit, improper ventilation or refrigeration, or unnecessarily rough handling of cars may contribute to rapid deterioration of the shipment on arrival.

The lack of proper refrigeration facilities at distributing centers is a cause of much loss. When produce moves slowly, there is often much spoilage before complete sales can be made. Rough handling during unloading or carting is another important cause of loss. As a matter of fact, the opportunities for losses due to the spoiling of commodities are so manifold that it is impossible to enter into a complete discussion of them.

In any discussion of losses and wastes it is always well to bear in mind the really serious side of this question. The spoiling of a dozen cantaloupes, a basket of grapes, or a crate of strawberries represents an absolute loss to the community. No benefit accrues to producer, distributor, or consumer from such a condition. The loss occurring at this point must be borne both by producer and consumer, and in a great many cases the distributor must bear his part of the burden. In many cases losses and wastes are entirely too heavy a tax on food distribution. It is probably safe to say that the elimination of unnecessary wastes would do as much toward effecting permanent, substantial economies in marketing and distributing as any readjustment of present marketing methods could do. The fact that a large percentage of these losses can be avoided by proper grading, packing, and shipping, together with prompt, efficient handling while the goods are in process of distribution, makes it imperative that this subject be given special consideration by those interested in the efficient marketing of farm crops.

CONCLUSION.

The car-lot movement of fruits and vegetables from distant production areas to large distribution centers has assumed its present importance during the last 20 years. This means that our present marketing methods are of comparatively recent origin. Many believe that the solution of present marketing problems would be reached by a return to the simple, direct methods which sufficed for the preceding generation. It should be borne in mind, however, that our present market machinery has been evolved because changing conditions of supply have made necessary many changes in the methods of handling food products.

A knowledge of the manner in which perishables were handled and marketed 40 years ago helps very little toward solving present difficulties. Any intelligent attempt to better marketing conditions must be based on a good working knowledge of present agencies and their functions. The nearer that both producer and consumer can come to an understanding and appreciation of the work devolving upon the distributor, the nearer will we approach a solution of many of the problems incident to the movement of fruits and vegetables.

A better knowledge of present methods of marketing would assist greatly in clearing away many problems, even though no changes in the present scheme of distribution were made. The shipper who has a more or less definite knowledge of the course his goods will take when they reach a big market has a great advantage over the man who has no idea of methods of distribution. He can safeguard his interests by retaining a measure of control over his product after it reaches destination.

Shippers or prospective shippers of fruits and vegetables are advised to get in touch with their principal market, learn its likes, dislikes, and peculiarities, study the means whereby their goods are distributed to consumers, and secure a working knowledge of the chief problems incident to the handling of their commodities.

SUMMARY.

1. In treating the subject of market distribution of fruits and vegetables, an effort has been made to explain certain general practices at large distribution centers which receive fruits and vegetables in car-lot quantities.

2. The widening distance between producer and consumer has called into existence the middleman of to-day. The fact that the middleman has certain useful functions to perform makes it inadvisable to eliminate him without arranging for some other agency to assume his duties.

3. The shipper who starts a car toward market should notify the consignee in such detail that prompt disposition of the goods may be made after the arrival of the car. This notification is often made by telegram and should include all information necessary to insure the prompt acceptance and disposal of the shipment.

4. As perishables should always be inspected promptly on arrival at destination, the shipper should give shipping instructions which permit inspection without unnecessary delay at destination.

5. Rejecting shipments of fruits and vegetables is an all too common practice on large markets. Often rejection may be justified, as when goods have arrived in a greatly deteriorated condition, but sometimes the actual cause for rejection is simply a decline in the market price.

6. In case a buyer rejects a car the shipper has the option of selling elsewhere or making an allowance to the original purchaser in order to close the transaction immediately. Claims against railroads should be filed in proper form and supported by a presentation of the facts in the case.

7. Perishables after arrival at market pass on to the consumer through many channels. Often, however, one firm may combine the functions of several middlemen, so that while there are many types of distributors it does not follow that goods actually change hands as often as a scrutiny of the list of middlemen might seem to indicate.

8. The fact that large cities secure supplies of fruits and vegetables from distant producing areas has been one of the main causes of increasingly complex marketing methods.

9. Brokers act as shippers' or buyers' agents. They handle car lots only and offer their services at very low rates. While many brokers are charged with abusing their privileges, they often save the shipper several times the brokerage fee by insuring the acceptance of goods at destination.

10. Fruit auctions sell goods for shippers, dealers, and others who have local representatives to withdraw offerings if prices are unsatisfactory. They secure their revenue by levying definite assessments against each package sold, and by attracting buyers and stimulating competition often expand the market for particular commodities.

11. The car-lot wholesalers constitute one of the most important factors in our large terminal markets. They handle great quantities of perishables annually and act as primary distributors of produce arriving at market in car-lot quantities.

12. The commission merchant receives goods on consignment and acts as the shipper's agent in disposing of these products to the jobbing and retail trade. While the commission merchant is viewed with much suspicion by many shippers, he nevertheless is a very

important factor in that he furnishes to shippers the services of a skilled specialist in salesmanship.

13. The jobber acts as a secondary distributor, buying from carlot receivers and selling largely to the retail trade. His chief usefulness lies in facilitating rapid distribution of highly perishable products and in preventing a congestion of business on large wholesale markets.

14. Public markets are not important in distributing fruits and vegetables arriving at market in car lots, but do offer direct outlets for neighboring producers.

15. Perishables arriving at market usually take certain definite channels in passing on to the consuming public. There are several important factors which decide just what course the contents of any given car will take in going into consumption.

16. Losses and wastes are a very heavy tax on food distribution. The prevention of much needless waste would reduce present marketing costs very materially.

17. One of the most practical steps the shipper can take to better his condition is to familiarize himself with business practices and to secure a better knowledge of the way his produce is handled on the market.

GLOSSARY OF TRADE TERMS AND EXPRESSIONS AS USED IN THIS BULLETIN.

Account sales. The statement which a commission merchant renders to a shipper showing what disposition has been made of the shipper's goods.

Allowance. The reduction in price which a shipper makes to a buyer in order to induce the buyer to accept a car that he (the buyer) has rejected.

Auctions. Organizations (usually incorporated as stock companies) which sell fruits at public sale to the highest bidder, charging a definite fee for this service.

Auction catalogues. Sheets in which the auction offerings for the day are listed.

Auction lines. The units into which auction offerings are divided before being exposed for sale. Each line is composed of packages of one commodity of the same size, grade, and type.

Auction realizer. A statement which shows the prices at which goods were sold by the auction.

Auction terminal charge. A package charge levied on the buyers by some auctions. Supposed to cover the expenses of opening sample lines for inspection and general expenses of the auction company.

Bill of lading. A written statement issued by a carrier acknowledging the receipt of goods for transportation. A "straight" bill of lading simply authorizes the carrier to deliver the goods to the consignee at destination. An "order notify" or "shipper's order" bill of lading requires that an order be issued by the shipper before delivery of the shipment can be made.

Brokers. Agents who negotiate the purchase or sale of goods. They have no financial interest in the goods they handle and their compensation is a definite fee.

- Broken car.** A trade term referring to a car from which a part of the contents have been removed.
- Car-lot assembler.** A term commonly applied to country merchants or buyers who purchase in small lots and combine into car-lot quantities.
- Car-lot wholesalers.** Distributors who buy fruits and vegetables in car-lot quantities and sell to the jobbing or retail trade.
- Commission merchant.** A dealer on the market who receives shipments on consignment and sells to the best advantage, remitting the proceeds to the shipper after deducting freight, drayage and other expenses, and a specified commission.
- Consignee.** A party to whom goods are consigned or shipped.
- Cooperative associations.** Organizations of producers incorporated for the purpose of grading, packing, shipping, or selling products grown by members of the association.
- Distributors.** Individuals, corporations, or associations whose business it is to route, distribute, or market agricultural products.
- Draft.** A written order from one person to another to pay to the order of the drawer or of a third person a stated sum of money. In the marketing of perishable products the term "draft" is used most frequently to designate that document which is attached to the bill of lading and forwarded through the banks for collection.
- Invoice.** A statement sent to a consignee which gives a list of goods which have been shipped to the consignee in question.
- Jobbers.** Dealers at distributing centers who buy, usually in less than car-lot quantities, from car-lot wholesalers or commission merchants and who in turn sell to the retail trade.
- Jobbing price.** The price at which the jobber buys his goods.
- Middlemen.** According to popular usage this term applies to all those who share in the profits and losses incident to the handling of goods between the producer and consumer.
- Operators.** Large wholesale firms which send their buyers or solicitors into producing sections and which, through representatives or branch houses in several large markets, secure a wide distribution for products which they purchase or handle on consignment.
- Private exchanges.** Distributing organizations incorporated as stock companies and operated for profit. They distribute car-lot shipments for individual shippers or producers' organizations, selling through salaried representatives or brokers.
- Protest, acceptance under.** Acceptance of a car by the consignee with the proviso that he reserves the right to enter claim later against the railroad.
- Retailing.** According to strict interpretation this term refers to sales made by the retailer. On large terminal markets, however, selling to the retail trade is popularly referred to as retailing.
- Vendee.** One to whom a sale is made.
- Vendor.** One who makes a sale.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

- Demurrage Information for Farmers. By G. C. White. Pp. 27, 1915. (Department Bulletin 191.)
- A System of Accounting for Cooperative Fruit Associations. By G. A. Nahstoll and W. H. Kerr. Pp. 25, 1915. (Department Bulletin 225.)
- Strawberry Supply and Distribution in 1914. By Wells A. Sherman, Houston F. Walker, and O. W. Schleussner. Pp. 10, 1915. (Department Bulletin 237.)
- Outlets and Methods of Sale for Shippers of Fruits and Vegetables. By J. W. Fisher, J. H. Collins, and Wells A. Sherman. Pp. 28, 1915. (Department Bulletin 266.)
- The Potato as a Truck Crop. By L. C. Corbett. Pp. 24, 1910. (Farmers' Bulletin 407.)
- Storing and Marketing Sweet Potatoes. By H. C. Thompson. Pp. 15, 1913. (Farmers' Bulletin 548.)
- Shipping Eggs by Parcel Post. By Lewis B. Flohr. Pp. 20. (Farmers' Bulletin 594.)
- Retail Public Markets. By G. V. Branch. Pp. 167-184. (Separate 636 from Yearbook 1914.)
- Cooperative Marketing and Financing of Marketing Associations. By C. E. Bassett, C. W. Moomaw, and W. H. Kerr. Pp. 185-210. (Separate 637 from Yearbook, 1914.)

PUBLICATIONS FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

- The Cold Storage of Small Fruits. By S. H. Fulton. Pp. 28, pls. 3, 1907. (Bulletin 108, Bureau of Plant Industry.) Price, 15 cents.
- Factors Governing the Successful Storage of California Table Grapes. By A. V. Stubenrauch. Pp. 31, pls. 8, figs. 5, 1913. (Department Bulletin 35.) Price, 10 cents.
- Cooperation in the Handling and Marketing of Fruit. By G. Harold Powell. Pp. 391-406. (Separate 546 from Yearbook, 1910.) Price, 5 cents.
- The Precooling of Fruit. By A. V. Stubenrauch. Pp. 437-448. (Separate 550 from Yearbook, 1910.) Price, 5 cents.
- Systems of Marketing Farm Products, and Demand for such Products at Trade Centers. By George K. Holmes. Pp. 391. (Report 98, Office of the Secretary.) Price, 25 cents.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 268

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.



July 20, 1915.

CROP PRODUCTION IN THE GREAT PLAINS AREA:

RELATION OF CULTURAL METHODS TO YIELDS.

By E. C. CHILCOTT, *Agriculturist in Charge*, and J. S. COLE and W. W. BURR,
Assistants, Office of Dry-Land Agriculture.

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INTRODUCTION.

This bulletin presents a summary of data obtained relative to the effect of cultural methods upon crop production in the Great Plains area. Six department bulletins have recently been published by the Office of Dry-Land Agriculture, dealing largely with this subject. In these are treated separately the effect of cultural methods upon the production of spring wheat, of oats, of corn, of barley, and of corn, milo, and kafir, and one deals with the effects of the time of plowing. The experimental results are presented in these bulletins in much greater detail than is possible in the present bulletin, and the reader is referred to them for the details of these investigations.¹

The investigations upon which these conclusions are based were conducted at 14 field stations, located at Moccasin and Huntley, Mont.; Williston, Dickinson, Hettinger, and Edgeley, N. Dak.; Belle Fourche, S. Dak.; North Platte and Scottsbluff, Nebr.; Akron, Colo.; Hays and Garden City, Kans.; and Amarillo and Dalhart, Tex.

¹ See bulletins of the United States Department of Agriculture bearing numbers and titles as follows: No. 214, "Spring wheat in the Great Plains area: Relation of cultural methods to production." No. 218, "Oats in the Great Plains area: Relation of cultural methods to production." No. 219, "Corn in the Great Plains area: Relation of cultural methods to production." No. 222, "Barley in the Great Plains area: Relation of cultural methods to production." No. 242, "Corn, milo, and kafir in the southern Great Plains area: Relation of cultural methods to production." No. 253, "The effect of different times of plowing small-grain stubble in eastern Colorado."

NOTE.—This bulletin is intended for all who are interested in the agricultural possibilities of the Great Plains area.

The Great Plains area to which the conclusions in this bulletin apply is shown by the map (fig. 1). The dots show the locations of the 14 field stations mentioned. The eastern boundary of the area is the ninety-eighth meridian and the western boundary is the 5,000-foot contour along the eastern foothills of the Rocky Mountains.



FIG. 1.—Sketch map of the Great Plains area, which includes parts of ten States and consists of about 400,000 square miles of territory. Its western boundary is indicated by the 5,000-foot contour. The location of each field station within the area is shown by a dot within a circle (○).

nations made at all the stations during the entire period is approximately 91,000.

The work has been conducted in cooperation with the State agricultural experiment stations in Montana, North Dakota, Nebraska, and Kansas, and with the Biophysical Laboratory, the Office of Western Irrigation Agriculture, and the Office of Cereal Investiga-

The altitude along the eastern boundary ranges from approximately 1,000 feet in the southeastern portion to 1,400 in the northeastern. The average altitude of the southern portion is higher than that of the northern. The length of the area from north to south is about 1,000 miles and the width from east to west about 400 miles. The area contains, therefore, about 400,000 square miles.

The period of time covered by the investigations at the several stations ranges from two to eight years. The aggregate of the years at all these stations is 80. The average number of the separate plats used each year is 1,900. The number of moisture determina-

tions of the Bureau of Plant Industry. The entire scientific staff of the Office of Dry-Land Agriculture, numbering about 30 men, has participated in the details of the field work and the preparation of the data for publication. The investigations have also had the benefit of the counsel and advice of the scientists connected with the various cooperating offices and State agricultural experiment stations.

CLIMATIC FEATURES OF THE GREAT PLAINS.

The climate of the Great Plains has been classified as semiarid. It may be better to say that it is variable. One season may have almost humid and another almost arid conditions. The mean annual precipitation is relatively low. Years of relatively high precipitation may be followed by years of relatively low precipitation. Other climatic factors usually correspond with the rainfall. In a year of relatively high rainfall there will be a lower rate of evaporation and higher humidity than in a year of low rainfall.

Another climatic factor of much importance in crop production on the Plains is the distribution of the rainfall. This is probably more important in crop production than the amount of annual rainfall. A relatively low rainfall, properly distributed, may produce a crop where a much higher rainfall, unfavorably distributed, may accompany a crop failure.

TABLE I.—*Annual and seasonal precipitation and seasonal evaporation at fourteen stations in the Great Plains area.*¹

Station.	Altitude (feet) ² .	Precipitation (inches) ³ .						Seasonal evaporation. ³		
		Annual.			Seasonal.					
		Mini- mum.	Maxi- mum.	Average.	Mini- mum.	Maxi- mum.	Average.	Mini- mum.	Maxi- mum.	Average.
Judith Basin.....	4,228	14.96	23.78	18.06	7.04	17.21	9.34	22.012	29.353	24.491
Huntley.....	3,000	11.92	11.92	11.92	5.92	6.02	5.97	23.754	24.214	23.984
Williston.....	1,875	10.28	18.99	14.84	4.75	14.49	9.66	20.422	26.877	24.216
Dickinson.....	2,543	11.93	21.22	16.69	6.85	16.28	9.79	20.673	25.745	23.919
Edgeley.....	1,468	11.94	21.95	16.71	7.85	14.98	10.11	18.663	24.893	21.866
Hettinger.....	2,253	12.72	15.68	14.20	8.92	12.47	10.36	21.539	28.239	24.639
Belle Fourche.....	2,950	6.64	17.73	13.11	4.08	9.78	6.90	26.472	33.750	28.794
Scottsbluff.....	3,950	13.77	18.51	16.14	2.53	8.52	4.69	23.804	29.381	26.081
North Platte.....	3,000	11.18	23.01	18.05	6.85	12.66	9.45	28.445	38.168	32.359
Akron.....	4,600	14.51	22.46	18.28	6.42	13.86	9.02	26.064	35.654	31.420
Hays.....	2,050	15.59	27.80	21.30	8.18	17.97	11.17	30.625	44.373	35.790
Garden City.....	2,900	11.82	23.58	18.54	2.79	14.43	8.65	34.325	43.510	38.185
Dalhart.....	4,000	13.69	16.35	15.11	5.09	9.85	8.01	35.459	41.748	38.988
Amarillo.....	3,676	10.69	27.80	18.28	6.17	11.38	9.13	33.804	42.076	36.724

¹ The years covered are the same as for the data shown in the tables for the several stations.

² The altitude given is for the field where the work was done and is based in most cases on that of the nearest town.

³ The records of annual precipitation for 1914 are not included. The records of seasonal precipitation and evaporation for 1914 are included for all stations, being figured from May 1 to Sept. 1. Evaporation measurements are made from a free water surface, in a tank sunk into the soil to almost its full depth. The water surface is kept about level with the surface of the ground.

Table I gives the maximum, minimum, and average annual precipitation and the seasonal maximum, minimum, and average precipitation and evaporation of the Great Plains area. By seasonal is meant the period between the average time of seeding and the average time of harvest.

Seasonal variations in climatic factors have been found in these investigations to be more important in determining crop production than have differences in methods of tillage. This is shown by the fact that at some stations in some years climatic conditions have been such that all methods have resulted in practical failures of the crops. In other years all methods have given fair returns.

Figure 2 shows the earliest and latest dates of the last killing frost in the spring, the earliest and latest dates of the first killing frost in the

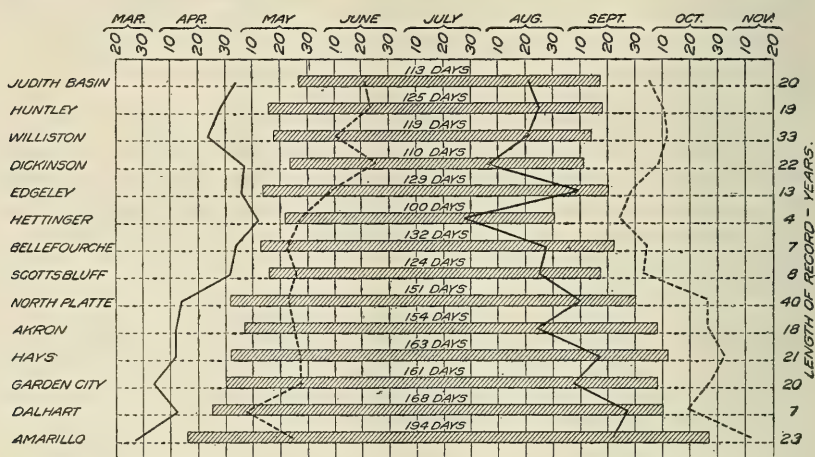


FIG. 2.—Diagram showing the average frost-free periods and the earliest and the latest dates at which the last killing frost in the spring and the first killing frost in the fall has occurred at fourteen stations in the Great Plains area.

the fall, and the average length of the frost-free period at each station. Each hatched horizontal bar represents the period between the average dates of the last killing frost in the spring and the first killing frost in the fall. The number of days in the average frost-free period for the station is shown in the figures above the bar. The solid-line curve at the left shows the earliest date at which the frost-free period has begun. The broken-line curve at the left represents the latest date at which the last killing frost of the spring has occurred. The solid-line curve at the right represents the earliest date and the broken-line curve at the right the latest date at which the first killing frost of the fall has occurred.

This diagram shows clearly the increase in the length of the frost-free period from the north to the south. The shortest average period is 100 days, at Hettinger, and the longest 194 days, at Amarillo. The

length of the period free from frost is more important in the production of corn than in the production of small grain. Young corn being easily injured by frost, planting must be delayed until there is little further danger from this source. Where the season is short, the crop may be caught by frost in the fall. This necessitates the use of short-season varieties in a portion of the Great Plains area.

SOILS OF THE GREAT PLAINS.

As would naturally be expected in so extensive an area, the soils of the Great Plains present a great diversity; but as it is only that portion of the area which is adapted to dry farming with which these studies deal, all of the alluvial bottoms, the sand hills, the "bad lands," and the rough, broken, and mountainous portions are eliminated. This elimination greatly reduces the diversity of soil types to be considered. The 14 field stations already mentioned were located with a view to having each of them on soil representative of extensive areas. It is believed, therefore, that the soils of these stations represent nearly all of the important soil types to be found in the strictly dry-farming portions of the Great Plains. The conclusions drawn from experiments conducted at these 14 stations, therefore, should apply to the Great Plains area as a whole, and those from individual stations, or from groups of stations, to extensive subdivisions of the area.

Space here will not permit of a detailed discussion of the soils at each station. Brief descriptions of the soils at these stations are given in a bulletin recently published.¹

CROPS AND CULTURAL METHODS.

The principal crops under investigation are spring wheat, winter wheat, oats, barley, corn, milo, and kafir. The methods of soil preparation include fall plowing, spring plowing, disking corn stubble, subsoiling, green manuring, and summer tillage, and listing for small grain, corn, milo, and kafir. Detailed descriptions of these various methods are given in the publications cited on page 1.

RESULTS OF METHODS TESTED WITH VARIOUS CROPS.

In this bulletin a table will be presented for each of the crops considered, the results for milo and kafir being combined in one table. The first part of each table shows the average yields obtained at each station by each method under trial. It also shows the number of years and total number of plats used in obtaining the average. In the case of the small grains only, the method of seed-bed preparation

¹ Bulletin U. S. Dept. of Agriculture No. 211, entitled "Spring Wheat in the Great Plains area: Relation of cultural methods to production," 43 p., 1915.

is considered, without reference to the previous crop. In the tables for corn, milo, and kafir, the tables show the effect of the previous crop, as well as the effect of the method. Under the headings, "Fall plowed," "Spring plowed," and "Green manured" in the tables for the small grains are shown the average yields obtained from ground so prepared following several different crops, usually wheat, oats, barley, or corn. The disked land has been chiefly corn land. Listing and subsoiling have been done on land continuously devoted to the crop for which results are presented. The second part of the table shows the comparative profit or loss resulting from growing each crop by the various methods under study. The profits and losses are based on the average yields shown in the first part of the table.

The method of computing the cost of production and of valuing the crop has been shown in detail in the publication previously cited.¹ The cost is based on a land rental of \$1.60 per acre and an average wage of \$2 per day for a man and \$1 per day for a horse. With this wage as a basis, the labor cost is computed on the average amount of work required by each method under trial. The cost of production as computed is not offered as being absolute for any locality, either in amount or cost of labor required, but is given as a working basis for the comparison of the results from different methods of preparation.

SPRING WHEAT.

The results with spring wheat are summarized in Table II. In the first part of the table are brought together for each station the average yields as grouped for this study under different methods of preparation. In the second part of the table the profit or loss in dollars and cents per acre for the average crop for each method is shown. This digest is based on the yield data presented in the first part of the same table.

When fall plowing following corn, oats, and wheat is averaged together and compared with spring plowing following the same crops, the average yields from each of the two methods at 11 of the 14 stations show no material difference for the years averaged. At only three stations—Scottsbluff, Akron, and Hays—are the average differences greater than 1 bushel per acre. At Hays the advantage is with fall plowing and at the other two stations with spring plowing. At most stations the advantage of one method over the other depends chiefly upon the season. The effect of different times of plowing small grain stubble has been treated in detail in a separate publication. The small difference in the cost of the two methods makes relative profits and losses from them follow closely the differences in yields.

¹ U. S. Dept. of Agriculture Bulletin No. 214, entitled "Spring Wheat in the Great Plainsarea: Relation of cultural methods to production," 1915, p. 8-11.

TABLE II.—Average yields and digest of cost of production per acre of spring wheat by different methods of tillage at fourteen stations in the Great Plains area.

Points covered.	Fall plowed.		Spring plowed.		Disked.		Listed.		Subsoiled.		Green. Manured.		Summer tilled.		Number of years averaged.
	Number of plots.	Average yield.	Number of plots.	Average yield.	Number of plots.	Average yield.	Number of plots.	Average yield.	Number of plots.	Average yield.	Number of plots.	Average yield.	Number of plots.	Average yield.	
Yields (bushels):															
Judith Basin.....	25	22.1	24	21.7	40	22.5	5	21.7	5	22.8	10	20.4	19	20.8	5
Huntley.....	8	20.0	6	19.5	16	22.4	2	18.0	2	16.0	4	22.3	6	25.9	2
Williston.....	20	15.3	15	15.9	35	16.2	.....	.....	.....	.....	10	18.6	15	20.2	5
Dickinson.....	30	20.1	18	19.8	54	23.3	.....	.....	.....	.....	30	22.2	18	27.5	6
Edgeley.....	32	15.3	30	15.5	86	17.7	.....	.....	.....	.....	23	16.7	37	17.9	8
Hettinger.....	15	13.4	9	13.7	36	15.7	.....	.....	.....	.....	12	14.6	24	20.4	3
Belle Fourche.....	24	7.0	18	6.5	72	8.8	6	7.5	6	6.7	24	9.2	30	11.5	6
Scottsbluff.....	15	9.6	12	11.5	33	14.0	3	9.4	3	9.4	6	13.3	9	19.9	3
North Platte.....	40	11.6	32	10.6	67	10.5	.....	.....	.....	.....	.....	.....	24	16.8	8
Akron.....	34	9.4	20	12.3	24	11.2	6	8.6	6	7.4	18	9.9	12	14.6	6
Hays.....	25	6.6	15	4.8	5	7.0	5	6.7	5	6.4	.....	.....	10	8.0	5
Garden City.....	30	4.1	14	3.1	10	4.6	5	5.1	5	4.2	8	3.7	15	6.0	5
Dalhart.....	20	2.2	16	1.9	12	1.8	4	5.4	.....	.....	8	0.3	8	5.8	4
Amarillo.....	27	6.2	21	6.1	6	6.6	6	7.4	6	8.1	12	8.6	18	12.6	6
Cost of production.....		\$6.56		\$6.09		\$4.75		\$5.55		\$7.17		\$14.61		\$11.50	....
Profit or loss (—):															
Judith Basin.....		8.91		9.10		11.00		9.64		8.79		— 0.33		3.06	5
Huntley.....		7.44		7.56		10.93		7.05		4.03		1.00		6.63	2
Williston.....		4.15		5.04		6.59		.....		.....		— 1.59		2.64	5
Dickinson.....		7.51		7.77		11.56		.....		.....		.93		7.75	6
Edgeley.....		4.15		4.76		7.64		.....		.....		— 2.92		1.03	8
Hettinger.....		2.82		3.55		6.24		.....		.....		— 4.39		2.78	3
Belle Fourche.....		—1.66		—1.54		1.41		— .30		—2.48		— 7.17		—3.45	6
Scottsbluff.....		.16		1.56		5.05		1.03		— .59		— 5.30		2.43	3
North Platte.....		1.56		1.33		2.53		.....		.....		.....		.26	8
Akron.....		.02		2.52		3.09		.47		—1.99		— 7.68		—1.28	6
Hays.....		—1.94		—2.73		.15		— .86		—2.69		.....		—5.90	5
Garden City.....		—3.69		—3.90		—1.53		—1.98		—4.23		—12.02		—7.30	4
Dalhart.....		—5.51		—5.23		—3.91		—3.03		.....		—14.47		—8.77	6
Amarillo.....		—2.22		—1.82		— .13		— .37		—1.50		— 8.59		—2.63	6

Wheat on disked corn ground has given consistently high yields. This, together with the low cost of this preparation for wheat, has resulted in its uniformly showing the greatest profit per acre at those stations where wheat has been produced at a profit and the least loss at those stations where wheat has been produced at a loss by all methods. The only exception to this is at Dalhart, where yields have been so low as to be of little practical moment. The realization of these profits depends, of course, upon the profitable production of corn, in competition with other crops, as a general farm crop.

It should be borne in mind that at all stations disking corn ground as a preparation for all small-grain crops has been done on corn land kept free from weeds. If weeds were allowed to develop in the corn, similar results should not be expected. To the extent that the weeds developed or were unhindered in their growth would the corn ground approach a grain stubble in the condition of the seed bed. If they matured seed, further damage might be done by their growth in the succeeding crop.

Subsoiling, as compared with fall plowing similar wheat stubble without subsoiling, has been of doubtful utility as a means of increasing yields. As a means of overcoming drought it is without value. At Judith Basin and Scottsbluff it has shown a small increase in yield over a comparable plat fall plowed without subsoiling, but the increase was hardly sufficient to pay the extra labor costs. The evidence from eight stations, some of which have eight years' records, indicates that working the soil to a greater depth than is reached by the ordinary plow is not essential. This indication is strengthened by data from other work not yet published on deep plowing and dynamiting.

Listing wheat stubble instead of plowing it in the fall has resulted in a small increase in yield at seven of the eight stations where it has been tried. At Amarillo it has increased the yields in the years of heaviest wheat production. At the same station it shows a slight loss in the average for all years when compared with a comparable plat fall plowed. As it is a somewhat cheaper method of preparation than fall plowing it has been a more profitable one.

Except at Judith Basin and Akron, wheat after summer tillage has given the highest average yields at each station of any method under trial. At Akron the yield of wheat on summer-tilled land has been exceeded by that on spring-plowed corn ground by 0.3 of a bushel per acre. The average of spring plowing is, however, below the average of summer tillage. The reason for the departure at Judith Basin is doubtless that of the depth and type of soil at that station. For the whole 14 stations under study the average increase in yield over disked corn ground has been 3.1 bushels per acre. Summer tillage requires the use of the land for two years to produce a crop and requires an extra amount of cultivation to keep it free from weeds in the fallow year. It consequently has the highest acre cost of any method under trial except its modification—green manuring. A study of the relative profits and losses from different methods, as given in Table II, shows that the increase in cost of production by summer tillage has been relatively greater than the increase in yields resultant from it. It has not at any station been the most profitable when a profit was realized, nor has it been the source of the least loss where wheat has been raised at a loss. At six stations it shows a profit, but a smaller one than was realized from some other method or methods. At four other stations it has resulted in a loss, while some other methods have resulted in profit. At the remaining four stations its practice has increased the loss attending the use of less expensive methods.

Green manuring is the most expensive method under trial. It resembles a fallow in that it requires the use of the land two years to produce one crop, but it has the added expense of seed and seeding.

There is a saving in cultivation during the spring while the green-manure crop is growing, but this is partially offset by the necessity of a second plowing to turn this crop under and is not sufficient to make up for the cost of seed and seeding. The yields have not been commensurate with the increase in the cost of producing them. At no station have the average yields following any green manure exceeded those from summer-tilled land. At all stations except Huntley and Dickinson the result has been a monetary loss, both actually and in comparison with other methods. These are the two stations that have had the highest average yields.

It is hardly fair to charge the whole expense of green manuring to the one crop that immediately follows it, as is here done, as it should have a cumulative effect in building up the soil or remedying its deficiency in organic matter. The available evidence is that on normal soils in the Great Plains area, at least in the first years of the work, little effect is shown on any other than the first crop. This effect is like that of a fallow, in that water is stored during the period after the crop is plowed under.

WINTER WHEAT.

Cultural methods for winter wheat have been under trial at all stations except those in North Dakota. No varieties at present available have sufficient hardiness to survive the winters in that State. In the rest of the Great Plains winter wheat is more successful. In dry falls there is trouble in getting germination and a good stand with some methods. At some of the stations there is more or less trouble with winterkilling. When winter wheat fails to start in the fall or to survive the winter it can often be successfully replaced with spring-sown varieties. When it survives the winter, it is quite generally more productive than spring wheat. At those stations where it is adapted it makes a greater response to cultural methods, particularly to summer tillage, than does spring wheat. Table III presents the average yields and the average profit or loss from each cultural method at each of the stations at which the crop has been under trial.

At Garden City, Dalhart, and Amarillo there have been so many failures and such poor yields when a crop was produced that the averages are very low. At these three stations the only material difference in the results from different methods has been a small increase in yields on summer-tilled land at Amarillo. This increase in the crop has not been proportionally as great, however, as the increase in the cost of production by the use of this method. The only profit from winter wheat by any method at these three stations has been 8 cents per acre on disked corn ground at Amarillo.

At the Judith Basin and Huntley stations the season is so short that it is not possible to make much difference in the time of plowing for winter wheat. The difference has been in depth of plowing rather

than in time of plowing, the plat under the heading "Late fall plowed" having been plowed shallower than the one headed "Early fall plowed." At Huntley the results seem to have favored shallow plowing. The chief thing to be noted in the results from these stations is the general lack of difference in the yields from methods other than summer tillage. At the Judith Basin station summer tillage has increased the yields from five to six bushels per acre. The increase has not been sufficient to pay for the increased cost of production by this method. Huntley has only two years' record. During these years the average yield of winter wheat on summer-tilled land has been over 40 bushels per acre as compared with yields of about 30 bushels from other methods. This makes both the yield and the profit from winter wheat after summer tillage at this station greater than by any other method at any station.

TABLE III.—Average yields and digest of cost of production per acre of winter wheat by different methods of tillage at ten stations in the Great Plains area.

Points covered.	Early fall plowed.		Late fall plowed.		Disked.		Listed.		Subsoiled.		Green manured.		Summer tilled.		Number of years averaged.
	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	
Yields (bushels):															
Judith Basin.....	5	19.8	5	20.2	4	22.5	5	19.8	5	20.0	2	23.5	8	25.7	5
Huntley.....	1	25.7	1	30.8	8	29.5	1	26.2	1	27.8	8	32.4	6	41.1	2
Belle Fourche.....	6	11.6	6	8.4	.....	.....	6	9.7	6	10.5	.....	.....	6	18.4	6
Scottsbluff.....	3	10.6	3	6.4	9	14.8	.....	.....	.....	.....	6	15.3	6	19.9	3
North Platte.....	.....	10.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30.8	3
Akron.....	5	14.1	5	13.3	15	19.2	5	14.7	5	11.8	40	16.7	10	21.8	5
Hays.....	7	15.8	7	11.6	28	12.4	7	19.4	7	19.1	34	14.2	13	21.7	7
Garden City.....	7	1.1	7	1.2	14	1.5	13	1.5	7	1.1	53	2.6	7	2.8	7
Dalhart.....	4	2.5	4	3.0	9	0	4	2.5	.....	.....	24	0	7	3.3	4
Amarillo.....	6	8.2	6	7.2	12	6.9	6	6.4	6	6.9	36	7.7	12	10.7	6
Cost of production.....	\$6.56		\$5.85		\$4.75		\$5.55		\$7.17		\$14.61		\$11.50		....
Profit or loss (—):															
Judith Basin.....	7.30		8.29		.....		8.31		6.83		.....		6.49		5
Huntley.....	11.43		15.71		15.90		12.79		12.29		8.07		17.27		2
Belle Fourche.....	1.56		.03		.....		1.24		.18		.....		1.38		6
Scottsbluff.....	.86		— .63		5.67		.....		.....		— 3.90		2.43		3
North Platte.....	.86		.....		.....		.....		.....		.....		10.06		8
Akron.....	3.31		3.46		10.69		4.74		1.09		— 2.92		3.76		5
Hays.....	4.50		2.27		3.93		8.03		6.20		— 4.67		3.69		7
Garden City.....	—5.79		—5.01		—3.70		—4.50		—6.40		—12.79		—9.54		6
Dalhart.....	—4.81		—3.75		.....		—3.80		.....		.....		—9.19		4
Amarillo.....	— .82		— .81		.08		—1.07		—2.34		— 9.22		—4.01		6

At North Platte, data for a sufficient number of years to be of value are available for only two methods, early fall plowing of land continuously cropped to winter wheat and summer tillage. The average yield from summer tillage has been 30.8 bushels and from continuous cropping only 10.6 bushels per acre. At Belle Fourche, Scottsbluff, Akron, and Hays, early fall plowing has increased the yields over late fall plowing. A still greater increase has been obtained by growing

the crop on summer-tilled land. The increase in yield at all of these stations except Hays has been sufficient to justify the use of this method for winter wheat if the results are to be compared with those from wheat stubble plowed in the fall.

At Akron the greatest profit has been realized from the growth of the crop on disked corn ground. At Hays land treated with the lister after harvest and land subsoiled have given decidedly the greatest profits.

The yields following the plowing under of rye or peas for green manure have approached, but in no case equaled, those on summer-tilled land. The greater cost of the method removes it from competition with other methods.

OATS.

In Table IV are brought together for the several stations the average yields of oats and the cost of production data as grouped for study under different methods of preparation, showing the profit or loss per acre for the average crop for each method for which it has been computed at each station.

TABLE IV.—Average yields and digest of cost of production per acre of oats by different methods of tillage at fourteen stations in the Great Plains area.

Points covered.	Fall plowed.		Spring plowed.		Disked.		Listed.		Subsoiled.		Green manured.		Summer tilled.		Number of years averaged.
	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	
Yields (bushels):															
Judith Basin.....	42	49.9	20	51.2	28	53.3	5	49.9	5	49.5	20	54.8	15	58.4	5
Huntley.....	12	43.4	8	49.2	16	53.0	2	47.2	2	46.1	8	58.6	6	59.2	2
Williston.....	30	33.5	20	36.2	20	37.9	.....	.....	.....	.....	10	39.1	15	43.9	5
Dickinson.....	36	34.4	42	36.9	30	47.5	.....	.....	.....	.....	18	44.0	18	49.9	6
Edgeley.....	51	32.2	39	31.4	49	33.5	.....	.....	.....	.....	21	35.1	34	38.3	8
Hettinger.....	18	22.8	21	32.0	21	35.1	.....	.....	.....	.....	9	22.2	15	32.1	3
Belle Fourche.....	36	16.1	24	18.0	48	21.9	6	18.8	6	17.5	24	22.4	30	29.8	6
Scottsbluff.....	21	18.2	18	22.2	24	26.3	3	20.4	3	20.4	15	28.7	12	38.2	3
North Platte.....	48	17.8	48	18.5	8	17.9	.....	.....	.....	.....	31	22.0	32	27.4	8
Akron.....	30	21.7	24	23.9	72	20.5	6	21.9	6	16.9	18	19.9	18	28.7	6
Hays.....	30	20.7	24	17.6	12	20.7	6	22.9	6	22.7	.....	.....	12	24.8	6
Garden City.....	25	8.7	20	6.0	65	8.8	5	12.8	5	9.2	10	9.2	15	12.8	5
Dalhart.....	16	4.5	12	3.5	44	4.0	4	5.9	.....	.....	8	.....	3	12	4
Amarillo.....	30	17.6	24	15.1	60	15.8	6	17.0	6	15.1	12	17.3	12	27.6	6
Cost of production.....	\$6.31		\$5.84		\$4.50		\$5.30		\$6.92		\$14.36		\$11.25		.....
Profit or loss (-):															
Judith Basin.....	8.66		9.52		11.49		9.67		7.93		2.08		6.27		5
Huntley.....	6.71		8.92		11.40		8.86		6.91		3.22		6.51		2
Williston.....	3.74		5.02		6.87		.....		.....		-2.63		1.92		5
Dickinson.....	4.01		5.23		9.75		.....		.....		-1.16		3.72		6
Edgeley.....	3.35		3.58		5.55		.....		.....		-3.83		.....		8
Hettinger.....	.63		3.76		6.03		.....		.....		-7.70		-1.62		3
Belle Fourche.....	-1.48		.44		2.07		.34		-1.67		-7.64		-2.31		6
Scottsbluff.....	.85		.82		3.39		.82		.80		-5.75		.21		3
North Platte.....	.97		.29		.87		.....		.....		-7.76		-3.03		8
Akron.....	.20		1.33		1.65		1.27		-1.85		-8.39		-2.64		6
Hays.....	.10		.56		1.71		1.57		.11		.....		-3.81		6
Garden City.....	-3.70		-4.04		-1.86		-1.46		-4.16		-11.60		-7.41		5
Dalhart.....	-4.96		-4.79		-3.30		-3.53		.....		-14.27		-8.46		6
Amarillo.....	-1.03		-1.31		.24		.20		-2.39		-9.17		-2.97		6

Perhaps the first thing that impresses one in viewing the average yields from all stations is the much greater adaptation of oats to the northern than to the southern section of the Plains. There is an almost constant decrease in yields from the northern, cooler, shorter season stations to the southern, warmer, longer season ones. This decrease is about the same for the heavier yielding as it is for the lighter yielding methods. This decrease in yield from north to south for all methods proves that the problem is one of adaptation of crops to conditions rather than one that can be overcome by cultural practices.

General averages for all of the stations mean little, as differences in yield obtained at one station by the combination of factors that determine yield may be balanced by differences in an opposite direction, as a result of a different combination of factors, at another station. With the trifling exception of a fraction of a bushel at Edgeley, spring plowing at all stations north of Hays has given higher average yields than fall plowing. At Hays and the stations south of it, fall plowing has been in about an equal degree better than spring plowing. The greater number of stations represented in the northern group makes the general average of averages show a small margin in favor of spring plowing. The general average, however, is of little value. It should not influence the practice at those stations whose results show fall plowing to be for them the best practice.

At all of the stations north of North Platte, disking has been productive of higher average yields than either fall or spring plowing. At North Platte, Dalhart, and Amarillo, it has been between the two in yield. At Hays it has yielded the same as fall plowing and higher than spring plowing. At Garden City it has yielded higher than either. In the general average of all the stations reported it has given a yield of 28.3 bushels per acre against 25.8 bushels for spring plowing and 24.4 bushels for fall plowing. The great bulk of the land disked is corn ground.

With the exception of a sharp decrease from subsoiling at Akron and a similar increase from listing at Garden City, the yields from each of these practices have not departed far from the yields of ordinary plowing.

Green-manured land has been productive of higher yields than either fall or spring plowed or disked corn ground at 9 of the 13 stations from which results from it are reported. At Dickinson it has given lower yields than disked corn ground. At Hettinger, Akron, and Dalhart it has yielded less than any of the three methods mentioned. At Amarillo fall-plowed land has exceeded it in yield.

Summer tillage has produced higher yields than any of the methods under trial at every station except Hettinger, where it has been exceeded only by disking corn ground. Averaged for all the stations,

its increase of yield over fall plowing has lacked one-tenth of a bushel of being 10 bushels per acre. The greatest departure from this general average is at Scottsbluff, where the increase has amounted to 20 bushels per acre.

As values and cost of production are here figured, it is seen in Table IV that oats have been produced at a profit by at least one method at all stations except Garden City and Dalhart. At two stations, Judith Basin and Huntley, a profit has been realized from all methods.

Comparatively good yields, combined with low cost of production, have usually made disked land, which has been chiefly corn ground, show the greatest profit at all stations where a profit has been realized from any method.

At all stations where it has been tried, listing has either been more profitable or has resulted in less loss than fall plowing.

Subsoiling has yielded a profit at two stations and a loss at six. It could not, however, be said that it was a profitable practice at any station, as the profits from it have been less and the losses from it greater than from fall plowing. It should be compared with fall plowing, as it is a modification of that method.

At all the 10 stations north of Hays, except Belle Fourche and North Platte, where the losses per acre have been \$0.44 and \$0.29, respectively, spring plowing has been productive of profitable crops. At Hays the average loss from it is only \$0.56 per acre. At Amarillo the loss has increased to \$1.31. At Garden City and Dalhart there was a loss, but all methods resulted in a loss at these stations.

At Akron and all North Dakota and Montana stations, fall plowing shows a profit. At Scottsbluff the nominal profits from spring plowing have been converted to nominal losses by fall plowing. At the other stations the losses from the two methods are about the same.

The cost of green manuring has been so high that at only two stations, Judith Basin and Huntley, has it shown a profit. At those stations the profits were smaller than those from any other method. At all other stations it has either converted the profit of other methods into a loss, or has been productive of the greatest loss. In probably only two or three cases has the loss been small enough to make it possible to change it to a profit by distributing a part of the cost to following crops.

Summer tillage as here figured shows a profit at six stations and a loss at eight. In two cases the profits are nominal—i. e., they are so small that changes in the average yields by extension of the record might change their position. In no case has the profit as here figured been as great as from some other method. Except at Dalhart and Garden City the losses at the eight stations showing a loss have averaged from \$1.62 to \$3.81. Considering the fact that summer

tillage sometimes produces a crop when other methods fail, it seems that it might have a place in the production of oats, even though somewhat greater net profits may be obtained in the average of a series of years by other methods. Surety of production, especially of feed crops, is as important, if not more important, than the amount of net profits per acre.

BARLEY.

In Table V are brought together for the several stations the average yields of barley from different methods of preparation. The profit or loss per acre for the average crop for each method for which it has been computed is also shown.

TABLE V.—Average yields and digest of cost of production per acre of barley by different methods of tillage at fourteen stations in the Great Plains area.

Points covered.	Fall plowed.		Spring plowed.		Disked.		Listed.		Subsoiled.		Green manured.		Summer tilled.		Number of years averaged.
	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	
Yields (bushels):															
Judith Basin.....	5	24.0	9	24.0	5	29.0	5	29.0	5	30.5	4	43.8	5	30.2	5
Huntley.....	5	17.4	10	16.1	5	27.5	.....	.....	.....	.....	.....	.....	5	28.8	5
Williston.....	6	25.1	12	24.6	6	37.4	.....	.....	.....	.....	.....	.....	5	32.5	5
Dickinson.....	8	16.7	16	18.5	8	23.4	.....	.....	.....	.....	.....	.....	5	20.0	5
Edgeley.....	3	19.9	6	25.5	3	14.9	.....	.....	.....	.....	.....	.....	5	31.8	5
Hettinger.....	6	7.6	12	8.3	6	12.2	6	7.7	6	8.0	.....	.....	5	12.6	5
Belle Fourche.....	2	14.0	4	15.4	2	18.6	2	14.4	2	15.0	.....	.....	5	27.6	5
Scottsbluff.....	8	17.1	16	15.9	8	13.4	.....	.....	.....	.....	.....	.....	5	26.7	5
North Platte.....	6	18.6	12	18.8	18	18.4	6	17.9	6	14.0	.....	.....	5	24.8	5
Akron.....	6	13.6	12	11.2	36	14.1	6	12.7	6	14.6	12	15.5	5	19.3	5
Hays.....	5	6.9	10	4.3	15	8.9	5	8.3	5	6.9	.....	.....	5	11.0	5
Garden City.....	4	3.9	8	1.9	12	1.6	4	4.4	.....	.....	.....	.....	4	6.4	4
Dalhart.....	6	8.2	12	5.7	6	6.6	6	6.1	6	6.8	.....	.....	6	12.6	6
Amarillo.....															
Cost of production.....		\$6.46		\$5.99		\$4.65		\$5.45		\$7.07		\$14.51		\$11.40	2
Profit or loss (—):															
Judith Basin.....		3.38		3.85		7.24		6.44		5.44		.....		.98	5
Huntley.....		.....		6.15		9.50		.....		.....		3.45		.....	5
Williston.....		.67		.61		6.63		.....		.....		.....		.41	5
Dickinson.....		3.83		4.10		10.68		.....		.....		.....		1.93	6
Edgeley.....		.39		1.60		4.94		.....		.....		.....		—3.20	5
Hettinger.....		1.70		4.47		1.46		.....		.....		.....		1.64	3
Belle Fourche.....		—3.34		—2.59		.35		—2.29		—3.79		.....		—6.23	6
Scottsbluff.....		— .72		.32		2.98		.45		— .92		.....		— .08	2
North Platte.....		.55		.53		.84		.....		.....		.....		— .45	5
Akron.....		1.17		1.72		2.89		1.89		—1.33		.....		—1.23	6
Hays.....		— .88		—1.40		1.13		— .24		—1.08		—8.15		—3.49	6
Garden City.....		—3.63		—4.23		—1.00		—2.05		—4.24		.....		—6.89	5
Dalhart.....		—4.86		—5.21		—3.96		—3.65		.....		.....		—8.78	4
Amarillo.....		—3.10		—3.65		—1.94		—2.95		—4.28		.....		—6.23	6

It is conspicuous in Table V that the yields at Belle Fourche, Garden City, Dalhart, and Amarillo have been markedly lower than at the 10 other stations. While some methods have increased the yields at these stations, they have not brought them up to a point that offers much encouragement for the growth of this crop. The

only profit shown at these stations from any method under study is one of 35 cents per acre from disking corn ground at Belle Fourche. This nominal profit has resulted from the low cost of production rather than from the amount of yield. The indications are that the combination of soil and climatic conditions at these stations is not congenial to the growth of barley, nor can the unfavorable conditions be overcome by cultural methods.

Table V also shows that at 10 of the 14 stations under study, disked corn ground has been productive of higher yields of barley than either fall or spring plowed stubble. At Hettinger and North Platte it has been clearly exceeded in yield by each. At Akron it has been exceeded in yield by both, but the differences between the three are only fractions of a bushel. At Amarillo it has been between the two in yield. Its low cost of production has made disking the most profitable method under trial at all stations except Hettinger. It has been productive of a profit at all stations except Garden City, Dalhart, and Amarillo.

Preparing the ground with a lister instead of a plow has been practiced at eight stations. At only one station, Judith Basin, have the yields been very materially different from those by fall plowing. At the other stations, although it has not in all cases given higher yields than plowing, owing to a lower cost of preparation, it has shown slightly more profit where profits are shown and less loss where losses are shown than has resulted from plowing.

The difference between spring and fall plowing is largely one of season. In the average of the 13 stations at which both were under trial, there is practically no difference. At only three stations is there a difference of over 2 bushels per acre in the yields from the two methods. At the four southern stations the advantage has been with fall plowing. This is the only consistent territorial difference to be noted in the comparison of these two methods, but production at these four stations and at Belle Fourche has been at a loss by both methods. Spring plowing shows a profit at all other stations and fall plowing at all others except Scottsbluff.

Subsoiling in preparation for the barley crop has been practiced at seven stations. At only two of these has the consequent yield departed far from that by fall plowing. At the Judith Basin station there has been a marked gain and at Akron a marked decrease from subsoiling. The cost of the method has been such that it has paid a profit at only the Judith Basin station.

The highest average yields at 11 of the 14 stations have been from summer-tilled land. At the Judith Basin station subsoiled land has yielded a fraction of a bushel higher. At Dickinson and Edgeley the yields on disked corn ground have been appreciably higher than on summer-tilled land. While the averages of all the stations are

not strictly comparable, summer tillage has increased the yield over fall and spring plowing of cropped land nearly one-half. The average increase over disking corn ground has not been nearly so great.

These increases in yields have not been in proportion to the increased cost of the method. In no case has it been the most profitable method under trial. As values and cost are here figured, this method shows a profit at only four stations, Judith Basin, Williston, Dickinson, and Hettinger. At Scottsbluff, North Platte, and Hays the losses have been small. At the other seven stations they have been sufficiently great to discourage the hope of changing them to profits by the extension of the record or by the adjustment of value or cost.

Green manuring for barley has been tried at only two stations, Huntley and Hays. At Huntley, where it was in comparison with only spring plowing and disking corn ground, it gave the highest yield. This average is the highest resulting from any method at any station. The record, however, is for only two years. At Hays the yield from this preparation has been higher than that on land from which a crop was harvested, but not as high as on summer-tilled land.

CORN.

In Table VI are assembled the average yields of corn produced by each method at the several stations. The profits or losses attending the use of each method in the production of corn are also shown.

Table VI shows that during the years covered by this work creditable average yields of grain have been obtained from all methods at Huntley, Williston, Dickinson, Scottsbluff, North Platte, and Akron, and from one method at Belle Fourche and Dalhart. No grain has been produced at either the Judith Basin station or at Garden City.

The corn is harvested either when mature or when growth is stopped by frost. It is cut with a binder and shocked in the field. The shocks stand until cured, usually about a month. They are then weighed, and the sound corn, if any, is husked and weighed. Where sound corn is produced, the yield as tabulated is given in bushels as "Grain." The term "Stover"¹ is used to show the total weight when no grain is produced and the difference between the weight of the grain and the total weight when corn is husked. The grain weights are converted into bushels on the basis of 70 to 75 pounds per bushel, depending upon the dryness at the time of husking.

There has been little difference in the average yields from the different cultural methods in use at Williston, Edgeley, Hays, and Amarillo. At Dickinson, Belle Fourche, and Dalhart, the only method of preparation giving yields departing far from the others has been

¹ In the tables of this bulletin only the term "stover" is used because the corn was husked whenever marketable or whenever it was produced in sufficient quantity to warrant husking. In cases where the yield of grain was not sufficient to warrant husking, the term "fodder" would be more exact.

summer tillage. At Dickinson this method has been responsible for a decrease and at Belle Fourche and Dalhart for an increase in yields.

TABLE VI.—Average yields and digest of cost of production per acre of corn by different methods of tillage at thirteen stations in the Great Plains area.

Points covered.	Fall plowed after—		Spring plowed after—		Sub-soiled after corn.	Listed after corn.	Summer tilled.	Number of years averaged.		
	Corn.	Small grain.	Corn.	Small grain.						
Yields per acre:										
Judith Basin.	{ Number of plats.. 5 Grain...bushels.. 0 Stover...pounds.. 5,744	{ 45 0 5,275	{ 5 0 6,002	{ 80 0 5,193	{ 5 0 6,130	{ 10 0 5,982	{ 5 0 5,656	}	5	
Huntley.....	{ Number of plats.. 2 Grain...bushels.. 14.0 Stover...pounds.. 1,380	{ 12 19.4 1,497	{ 2 21.8 1,375	{ 32 25.2 1,654	{ 2 19.8 1,945	{ 2 26.3 1,605	{ 2 26.1 1,695			
Williston.....	{ Number of plats.. 5 Grain...bushels.. 15.3 Stover...pounds.. 5,542	{ 20 12.8 1,743	{ 5 15.1 5,780	{ 60 14.1 6,537	{	{	{ 5 17.6 5,924			
Dickinson.....	{ Number of plats.. 6 Grain...bushels.. 19.9 Stover...pounds.. 2,105	{ 24 20.6 2,144	{ 6 21.5 2,362	{ 96 19.8 2,408	{	{	{ 6 14.5 1,822	}	6	
Edgeley.....	{ Number of plats.. 8 Grain...bushels.. 7.0 Stover...pounds.. 3,039	{ 40 8.2 3,201	{ 8 7.3 3,129	{ 160 8.4 3,245	{	{	{ 8 6.8 2,926			
Belle Fourche..	{ Number of plats.. 6 Grain...bushels.. 10.0 Stover...pounds.. 2,288	{ 24 8.1 1,655	{ 6 9.8 2,145	{ 102 7.8 1,724	{ 6 9.4 2,125	{ 6 10.3 2,129	{ 6 17.0 2,178			
Scottsbluff....	{ Number of plats.. 3 Grain...bushels.. 30.1 Stover...pounds.. 1,753	{ 27 24.5 2,516	{ 3 27.9 1,913	{ 60 27.5 2,770	{ 3 26.8 2,280	{ 3 24.9 1,740	{ 3 39.0 3,200	}	3	
North Platte..	{ Number of plats.. 8 Grain...bushels.. 18.2 Stover...pounds.. 2,383	{ 72 13.3 2,143	{ 8 18.5 2,438	{ 72 13.2 2,307	{	{	{ 8 20.8 2,711			
Akron.....	{ Number of plats.. 6 Grain...bushels.. 20.0 Stover...pounds.. 2,292	{ 72 12.9 1,769	{ 6 19.4 2,388	{ 54 13.7 1,746	{ 6 16.8 2,113	{ 12 13.9 1,962	{ 6 20.9 2,257			
Hays.....	{ Number of plats.. 6 Grain...bushels.. 6.2 Stover...pounds.. 3,226	{ 24 5.5 3,512	{ 6 6.1 3,668	{ 60 6.9 3,290	{ 6 8.3 3,486	{ 6 6.2 3,093	{ 6 9.9 3,929	}	6	
Garden City..	{ Number of plats.. 5 Grain...bushels.. 0 Stover...pounds.. 3,020	{ 55 0 2,768	{ 5 0 3,047	{ 55 0 2,688	{ 5 0 3,363	{ 10 0 2,819	{ 5 0 4,700			
Dalhart.....	{ Number of plats.. 6 Grain...bushels.. 8.6 Stover...pounds.. 2,711	{ 72 7.3 2,569	{ 6 9.5 2,725	{ 42 7.0 2,280	{	{ 6 14.0 2,588	{ 6 13.7 3,900			
Amarillo.....	{ Number of plats.. 7 Grain...bushels.. 5.8 Stover...pounds.. 2,491	{ 77 5.4 2,301	{ 7 5.1 1,921	{ 21 4.3 2,023	{ 7 6.0 2,481	{ 14 7.0 1,925	{ 7 8.6 3,037	}	7	
Cost of production.....										
Profit or loss (—):	\$7.49	\$7.49	\$7.11	\$7.11	\$8.18	\$5.98	\$12.36			
Judith Basin.....	4.00	3.06	4.89	3.28	4.08	5.98	—1.05	}	5	
Huntley.....	.87	3.26	4.36	6.28	3.63	7.75	1.47			
Williston.....	9.71	11.92	10.49	11.60	.....	.....	6.53			
Dickinson.....	4.67	5.04	6.21	5.63			—2.92	}	6	
Edgeley.....	1.38	2.19	2.07	2.74	.....	.....	—3.79			
Belle Fourche..	1.09	— .94	1.10	— .51	— .17	2.40	—1.20			
Scottsbluff....	8.06	7.34	7.88	9.43	7.10	7.46	9.64	}	3	
North Platte..	4.56	2.12	5.17	2.78	.....	.....	1.38			
Akron.....	5.09	1.21	5.43	1.86	2.77	3.50	.51			
Hays.....	1.44	1.73	2.67	2.23	2.11	2.69	— .54	}	6	
Garden City..	—1.45	—1.95	—1.02	—1.73	—1.45	— .34	—2.96			
Dalhart.....	1.37	.57	2.14	.25	.....	4.80	.92			
Amarillo.....	— .19	— .73	—1.23	—1.34	— .82	.67	—2.85	}	6	

Between the yields following fall and spring plowing, there is little general difference to be noted except at Huntley and Scottsbluff. At Huntley spring plowing has been better than fall plowing. At Scottsbluff fall plowing has been better than spring plowing where corn follows corn and poorer than spring plowing where corn follows small grain.

At some stations more difference is to be noted as a result of crop sequence than as a result of difference in time of plowing. At Huntley corn has been better after small grain than after corn. At North Platte and Akron corn after corn on both fall-plowed and spring-plowed land has been markedly better than corn after small grain.

It appears that the yields of fodder reported from the Judith Basin Field Station and from Williston are abnormally high. While the yields have generally been good at these stations, it is doubtful whether they have been as much higher than those at some of the other stations as these figures indicate. It is probable that in the years showing excessively high yields the crop had not been well dried at the time of weighing.

A very striking fact brought out is the uniformity in the amount of stover or fodder produced by all methods at the stations in Montana and North Dakota. So far as the production of rough feed is concerned, there appears very little difference in the yields from the various methods on which to make a choice. South of North Dakota there is a general agreement of heavier yields of stover or fodder where corn follows corn than where corn follows small grain except at Scottsbluff, where the yields have been heavier after small grain than they have been after corn.

Small differences in stover yields are to be noted between the results following spring and fall plowing. On the whole, the average yields by the two methods are almost the same.

The most noticeable effect resulting from cultural practice is the very marked increase in the yields of stover resulting from growing corn on summer-tilled land at the more southern stations—Garden City, Dalhart, and Amarillo. Only small increases in yields attended this practice at Scottsbluff, North Platte, and Hays.

Subsoiling has not markedly affected the yields, except at Akron, where it has decreased them.

Listing has materially increased yields at Huntley and at Dalhart. At the other stations the effect has not been marked.

Table VI shows that corn is relatively much less profitable at Belle Fourche, Garden City, Dalhart, and Amarillo than at the other stations.

Scottsbluff is the only station where summer tillage as a preparation for corn has shown the most profit of all methods. At most of the stations this has been the least profitable method. It has resulted

in actual loss at Judith Basin, Dickinson, Edgeley, Belle Fourche, Hays, Garden City, and Amarillo.

Another fact shown is the greater profit derived from the growth of corn after corn over corn after small grain at Akron and North Platte, and from corn following small grain over corn following corn at Huntley.

Listing has been tried at nine stations. Except at Scottsbluff and Akron it has been the most profitable method under trial. As has been pointed out, the relative profitableness of this method has been largely due to its low production cost rather than to increased yields.

A careful reading of the data given in Table VI will show that corn can not be profitably grown as a grain or cash crop in large portions of the Plains. At only 5 of the 13 stations have the grain yields been sufficiently large to indicate a possibility of the crop being profitably produced for the grain alone. At Huntley, Dickinson, Scottsbluff, North Platte, and Akron, enough grain has been produced by some methods to pay the cost of production and show small profits. Taken as a whole, however, the data show that in order to realize the full profit corn should be considered as a feed crop. To pay the cost of production, in many sections it is necessary to utilize the roughage produced. When this is done, the corn crop shows a profit at all stations except Garden City and Amarillo. It should therefore occupy a permanent place in the rotation except in the extreme southern portion of the area, as it leaves the soil in good condition for the crops that follow it.

MILO AND KAFIR.

The area to which milo and kafir are adapted has been shown in a previous publication.¹ Experimental work in methods of production of these crops has been done at Akron, Colo.; Hays and Garden City, Kans.; Dalhart and Amarillo, Tex.; and Tucumcari, N. Mex.

The latitude and altitude at Akron combine to make conditions generally unfavorable for either milo or kafir. In the production of grain they can not compete with corn. In the production of forage they can not compete with sweet sorghum.

At Hays both milo and kafir are of great value. The small area of the plats in the experimental work has subjected them to influences, such as ravages of insects, that are not generally experienced under field conditions. The data that have been obtained are not sufficient to permit adequate comparison either of results from different methods or of these crops with others.

At Tucumcari the work has not been carried on for a sufficient length of time to obtain averages that warrant the drawing of conclusions. Results from Akron, Hays, and Tucumcari are, therefore, not included in the tables.

¹ Farmers' Bulletin 322, by Carleton R. Ball and Arthur H. Leidigh.

Table VII presents for milo and kafir the average results of growing these crops under various methods at Garden City, Dalhart, and Amarillo. The average yields of both grain and stover at these stations by each of the methods under study and also the profit or loss resulting from raising the crop are shown.

TABLE VII.—Average yields and digest of cost of production per acre of milo and kafir by different methods of tillage at three stations in the Great Plains area.¹

Points covered.	Fall plowed.						Spring plowed, milo after milo, kafir after kafir.			Listed, milo after milo, kafir after kafir.			Summer tilled.		
	Milo after milo, kafir after kafir.			After small grain.											
	Number of plats.	Grain.	Stover.	Number of plats.	Grain.	Stover.	Number of plats.	Grain.	Stover.	Number of plats.	Grain.	Stover.	Number of plats.	Grain.	Stover.
Yields of milo:		<i>Bus.</i>	<i>Lbs.</i>		<i>Bus.</i>	<i>Lbs.</i>		<i>Bus.</i>	<i>Lbs.</i>		<i>Bus.</i>	<i>Lbs.</i>		<i>Bus.</i>	<i>Lbs.</i>
Garden City.....	6	8.8	2,152	10	10.5	2,556	6	6.2	1,873	6	8.8	2,036	.....	.....	.....
Dalhart.....	6	22.1	3,995	10	11.6	3,188	6	21.2	4,065	6	24.8	3,575	6	36.6	5,938
Amarillo.....	7	20.4	2,920	14	23.1	3,286	7	21.1	2,626	10	20.9	2,313	3	17.1	3,463
Yields of kafir:															
Garden City.....	6	6.6	3,262	10	6.9	4,229	6	4.7	2,910	6	4.5	2,943	.....	.....	.....
Dalhart.....	6	13.9	5,352	10	4.7	4,230	6	9.7	5,287	6	16.9	5,605	6	31.1	9,992
Amarillo.....	7	11.3	4,422	14	12.2	5,387	7	10.2	3,824	10	9.3	3,207	3	2.3	4,427
Cost of either crop.....		\$7.44			\$7.44			\$7.06			\$5.93			\$12.31	
Profit or loss (—) on milo:															
Garden City.....		.38			2.07			— .83			1.59			.....	
Dalhart.....		9.39			3.56			9.55			11.14			14.21	
Amarillo.....		6.56			8.37			6.63			7.06			1.46	
Profit or loss (—) on kafir:															
Garden City.....		1.72			3.78			.64			1.76			.....	
Dalhart.....		8.82			2.90			7.39			12.04			20.11	
Amarillo.....		5.92			8.21			4.67			4.20			—2.54	

¹ Number of years averaged: At Garden City and Dalhart, 6; at Amarillo, 7.

Both milo and kafir have given higher average yields than corn at each of these stations. They have also been safer crops, having made crops of grain in some years when corn did not. They have also been more responsive to cultural operations, thus proving their better adaptation to conditions. On the sandy lands of this area corn makes a better showing in comparison with these crops than it does on the heavy, tight lands. On these latter soils corn has little place in this section. Where a comparison is made between milo and kafir it is seen that milo has produced more grain than kafir and that kafir has produced more roughage than milo. Kafir, however, has shown a somewhat greater response to methods that increase the yields, such as summer tillage. When equal values are assigned to the grain and to the roughage from each of the crops, the total return is generally about the same from each. At Garden City the grain crop alone has not been sufficient to pay for the cost of production. At Dalhart both crops have produced sufficient grain by all methods to pay a profit. At Amarillo milo has returned a profit from the grain alone by some methods. The crop of kafir grain at this station has

not been sufficient from any method to pay the cost of producing the crop.

When a value, believed to be a conservative one, is assigned to the fodder, both crops show a profit from nearly all methods under trial at all the stations. The only two exceptions are milo following milo by spring plowing at Garden City and kafir by summer tillage at Amarillo. This latter has been on trial for only three years, all of which have been relatively unfavorable. At Garden City and at Amarillo the yields of both grain and fodder from both milo and kafir have been greater following small grain than following themselves on fall plowing. At Dalhart the reverse has been true except in the case of kafir forage.

Fall plowing has generally been a better preparation than spring plowing for both crops. At Amarillo the results with milo show little difference.

The yields following listing have not generally departed far in either direction from those on similar land spring plowed. The most marked departure is an increase in the yield of kafir as a result of listing at Dalhart.

Summer tillage as a preparation for these crops was not included in the experiments as originally outlined for Garden City. This defect has been remedied, but results of value have not yet been obtained. At Dalhart it has been the most productive and profitable method under trial. At Amarillo this method has been under trial for only three years. The results presented are not comparable with those from other methods. The data at hand indicate that marked increases in yields may be expected.

TILLAGE PRACTICES.

In the preceding pages data have been presented and discussed on each crop separately. The data and the experience gained and observations made during the investigations indicate that certain tillage practices are more or less general in their application. These will now be considered in their general application without reference to individual crops.

PLOWING AND ITS SUBSTITUTES.

In these investigations it has been assumed that the land should always be plowed for all crops following small-grain crops, except when it is ridged with a lister in the fall and cultivated down level in the spring without the use of the plow or when cultivated crops are planted with the lister. The practice of disking in small-grain crops on the stubble of the previous small-grain crop without plowing has not been tested sufficiently to warrant any definite recommendation at this time. This is a method that is sometimes resorted to in some

parts of the Great Plains on account of its low cost, and it might be justified under certain circumstances. If this method were practiced it would undoubtedly be necessary to grow intertilled crops at frequent intervals in rotation with small grain to avoid damage from weeds, insects, and diseases, which would soon reduce crop yields.

WHEN DISKING MAY BE SUBSTITUTED FOR PLOWING.

These investigations have shown that when the corn crop has been grown on properly prepared land and kept free from weeds, the land does not require plowing in preparation for a following crop of small grain. Wheat, oats, and barley have usually given better yields on disked corn land than upon land that has been plowed. This, together with the fact that disking is cheaper than plowing, makes disking corn land generally the most profitable method of preparation for small grain. Disking potato land is probably as good a preparation for small grain as disking corn land and there are undoubtedly other intertilled crops, such as peas, beans, and peanuts, that will serve the same purpose. The sorghums, however, do not leave the ground in as favorable a condition for the crop that is to follow as the other crops mentioned.

USE OF THE LISTER IN THE FALL.

The practice of ridging with a lister as a substitute for fall plowing and cultivating down level without the use of a plow in the spring has been tested at most of the stations as a preparation for all of the small-grain crops considered in this bulletin except winter wheat. It has usually produced as good or better yields than fall plowing. Its lower cost has made it in many instances nearly or quite as profitable a method as disking corn stubble. In addition to its low cost it has the advantages of catching and holding the snow and checking soil blowing during the winter and of arresting run-off.

When the lister is used in preparing land for winter wheat, the listing is done immediately after the harvest of the preceding crop. The soil is worked down level, usually with a disk, in late summer or early fall, and then seeded with an ordinary grain drill. Very little differences in average yields between listing and plowing have been noted except at Hays, where the advantage is in favor of listing.

PLANTING WITH THE LISTER.

When the lister is used for planting corn, kafir, and milo, the land is left undisturbed from the time of harvesting the preceding crop until planting time the following spring, when the crop is planted with a lister. The ridges are then cultivated down level during the growth of the crop. At Judith Basin, Huntley, Belle Fourche, and

Dalhart, listing has produced markedly better yields than surface planting. At Scottsbluff, Hays, Garden City, and Amarillo there has been little difference. At Akron the advantage has been decidedly in favor of surface planting.

THE OBJECTS SOUGHT BY PLOWING.

The principal objects which are sought by plowing and the subsequent preparation of the soil are to prepare a suitable seed bed for the germination of the seed and the early growth of the seedling, to make the surface soil more receptive to water falling as rain or snow, and to prevent the growth of weeds. It is also important to have the surface of the soil in such condition that it will neither blow when exposed to high winds nor puddle when subjected to heavy beating rains. The latter considerations are of special importance when a period of several months intervenes between plowing and seeding, as in the case of summer tillage or of early fall plowing for spring-sown crops. The surface should then be left in a rough, cloddy, or ridged condition and a fine dust mulch avoided.

DEPTH OF PLOWING.

The data submitted and discussed in this bulletin show that subsoiling has failed to give the most profitable yields of either spring or winter wheat, oats, barley, or corn, at any of the stations where it has been tested. These results are in accord with those of other investigations with deep tillage that have been conducted by the Office of Dry-Land Agriculture. The evidence so far obtained from the investigations goes to show that nothing is gained by stirring the soil to a depth greater than is done by ordinary plowing 8 inches or less in depth.

HOW AND WHEN TO PLOW.

The comparative average yields from fall and from spring plowing at each station for corn, spring wheat, oats, barley, milo, and kafir have shown but small differences. As the land requires plowing for all annual crops except in those cases above noted, and as plowing is an expensive operation, it is a question of great economic importance as to how and when this plowing should be done. Much has been written upon this subject and many theories have been developed and advocated, but the investigations conducted in the Great Plains by the Office of Dry-Land Agriculture seem to show conclusively that no set rule can safely be followed. The best practice seems to be to do a good, clean-cut, workmanlike job of plowing to a depth of 4 to 8 inches when the soil is in proper condition and the work can be done to the best advantage, taking into consideration the most economical distribution of labor throughout the year.

ACCESSORY TILLAGE.

Under the heading of accessory tillage may be included three distinct practices: (1) Summer tillage, or the tillage of an uncropped fallow field during an entire season; (2) shallow tillage after the crop is removed at harvest and before seeding in the following spring; and (3) the cultivation of an intertilled crop, like corn or potatoes, during the earlier part of the growing season. Each of the three practices above mentioned can again be subdivided into two groups, namely, tillage for the destruction of weeds and tillage for improving the physical condition of the soil.

DESTRUCTION OF WEEDS.

The destruction of weeds is nearly always desirable, as under dry-farming conditions weeds are one of the most serious obstacles to successful crop production. When summer tillage is practiced on a bare fallow during the entire season, cultivation should be frequent and thorough enough to destroy all weeds before they attain sufficient size to transpire appreciable quantities of water or to reseed themselves. This tillage will also keep the surface in a condition sufficiently loose and open to allow the rain that falls to penetrate it. When the soil becomes well filled with water early in the season and additional rains can reasonably be expected, it may sometimes be desirable to allow the weeds to attain a larger growth and then plow them under in order to provide additional organic matter in the soil, but it must be borne in mind that this gain in organic matter is made at the expense of the soil moisture.

Tables II to VII show that summer tillage is, with the exception of green manuring, the most expensive and least profitable method under trial. Exceptions are to be noted in the case of kafir and milo at Dalhart, corn at Scottsbluff, and winter wheat at North Platte and Huntley.

The purpose of summer tillage is accomplished by the prevention of vegetative growth rather than by the maintenance of a mulch. Numerous experiments made in connection with this work have furnished an abundance of evidence that when vegetative growth is restrained the loss of water from a mulched surface is practically the same as from an unmulched one.

The cheapest and most efficient methods of weed destruction necessarily form a soil mulch. The results accruing from the prevention of weed growth have been very generally attributed to the mulch itself when the mulch is, in fact, only incidental.

Tillage for the purpose of destroying weeds after harvest is warranted only in those exceptional cases when sufficient water remains in the soil to start weed growth after harvest or when heavy rains come soon after. In such cases early fall plowing is the most effective

method of destroying the weeds and thus saving the moisture that would be used by them if allowed to grow. The same object may be accomplished by disking soon after the weeds have started. This method has the advantage of being more rapid than plowing, thus making it possible to cover more ground with the same number of teams and men. But as the land will have to be plowed before another crop is sown, the labor of disking is mostly lost, although the labor of plowing the disked land may be somewhat less than if it were not disked and a better job of plowing may sometimes be done on the disked land. The cost of early fall plowing or disking, when the weather is hot and the men and teams are needed for stacking, thrashing, and hauling grain, is greater than later in the fall, when the weather is cooler and there is less other work for men and teams. All of these facts should be taken into consideration before going to the extra expense of tillage to kill weeds immediately after harvest.

Spring plowing or disking, as soon as the weed seeds have germinated, is usually a profitable practice. Where small grain is to be sown, the sowing should be done soon after plowing; but where corn, potatoes, or the sorghums are to be grown there is often a period of several weeks between the time of the germination of the weed seeds and the time when the season is sufficiently advanced to plant the crop. This period should be utilized as far as possible for the destruction of weeds before the crop is planted. Much labor in keeping the crop free from weeds during its growing period can thus be saved.

Harrowing small grain for the destruction of weeds after the grain is sown and until it has reached a height of 3 or 4 inches may sometimes be practiced to advantage. Experimental evidence does not show it to be generally profitable. Harrowing corn and potatoes after planting and until the young plants have attained a height of 2 or 3 inches is quite generally practiced to advantage.

It is absolutely essential for the most profitable growth of corn, potatoes, the sorghums, and, in fact, all the intertilled crops, that sufficient tillage be given to keep the growing crop free from weeds until the plants have attained such growth that they will be seriously injured by the cultivators or the horses.

IMPROVING THE PHYSICAL CONDITION OF THE SOIL.

As has been already shown, accessory tillage for the destruction of weeds usually will accomplish all that can be accomplished by tillage in keeping the soil in proper physical condition during the intervals between plowings. There is, however, one exception, namely, the accessory tillage immediately preceding the seeding of the crop for the purpose of preparing a suitable seed bed. The small-grain crops require a mellow surface and a firm condition of the soil below. In order to bring about this condition it is generally

necessary to resort to either harrowing or disking, or both. The deeper the plowing, the more thorough should this preparation be.

In the planting of corn, potatoes, and most other intertilled crops generally grown in the dry-farming regions, this accessory tillage between plowing and planting is not so essential. These crops do not require as firm a seed bed as the small grains, and there is also a better opportunity for such tillage immediately after the crop has been planted. Moreover, it has been found that when the plowing has been properly done, better germination and growth are generally secured where there is little or no stirring of the soil between plowing and planting except such as is necessary for the destruction of weeds.

REGIONAL ADAPTATION OF CROPS.

Spring wheat is adapted to the northern portion of the Great Plains. Its growth in North Dakota and Montana has been quite generally profitable in all years when seasonal conditions permitted the profitable production of any crop. Spring wheat is adapted, though in a somewhat lesser degree, to conditions in western South Dakota, western Nebraska, and eastern Colorado. It has not shown itself to be adapted to conditions in western Kansas, Oklahoma, Texas, and northeastern New Mexico.

Winter wheat will tend to replace spring wheat where it can be successfully grown. It has proved to be adapted to conditions in Montana, some parts of South Dakota, Nebraska, Colorado, and the major portion of Kansas. In southwestern Kansas and northwestern Texas it has not been profitably produced. It has given higher yields than spring wheat at Huntley, Belle Fourche, Scottsbluff, North Platte, Akron, and Hays.

Oats are better adapted to conditions existing in Montana and North Dakota than to those of any other sections of the Plains included in these investigations. They have been profitably grown by some method at Belle Fourche, Scottsbluff, North Platte, Akron, Hays, and Amarillo, but they have shown markedly less adaptation to the conditions at these stations than to those farther north. They are not at all adapted to conditions such as have existed at Garden City and Dalhart.

Barley, like spring wheat and oats, is better adapted to the northern than to the southern portion of the Plains. At North Platte and Akron it is less adapted but has been profitably produced. At Belle Fourche and Scottsbluff its growth is a questionable practice. In most of western Kansas and northwestern Texas its growth should be discouraged.

Corn has been grown at all the field stations in the Plains area. At only five stations, Huntley, Dickinson, Scottsbluff, North Platte, and Akron, has it shown possibilities for profitable production as a cash

grain crop. As a feed crop, which includes the utilization of both roughage and grain, it can be profitably grown in all sections north of the southern line of Nebraska and in eastern Colorado. In the northern portions of western Kansas it will compete with the sorghums as a feed crop. South of central Kansas some of the sorghum crops have been more profitable than corn.

Milo and kafir for both grain and feed are well adapted to conditions in western Kansas, western Texas, Oklahoma, and eastern New Mexico.

CONCLUSIONS.

These investigations furnish strong presumptive evidence upon which to base the following conclusions:

(1) When the climatic conditions are as favorable as those often experienced in all parts of the Great Plains area on all the types of soil represented at the 14 stations, profitable crops can be produced by any one of several different cultural methods such as are in common use.

(2) When the climatic conditions are as unfavorable as those often experienced in all parts of the Great Plains area on any of the types of soil represented, no profitable crop of any kind so far tested can be produced by any of the cultural methods that have been under investigation.

(3) Under the normal conditions prevailing in any part of the Great Plains for a term of 10 years on any type of soil represented at any of the stations, some crops can be produced at a profit when proper cultural methods are practiced, provided that the prices of labor and of farm produce bear the same relation to each other as those which have prevailed there during the last 10 years.

(4) No single crop tested in these investigations can be raised profitably in all parts of the Great Plains area on any type of soil by any cultural method so far tested.

(5) As forage crops of some kind can profitably be grown at all stations, they must occupy an important place in any system of farming adapted to the Great Plains. Sufficient live stock must be kept to convert these crops into finished products on the farm, and sufficient forage must be produced and stored during favorable seasons to carry the live stock through specially unfavorable seasons.

(6) Good farming is as essential to success in the Great Plains area as elsewhere. Good farming means practicing the best methods of producing the largest crops at the lowest relative cost of production and leaving the soil in the best condition for the production of subsequent crops. Good farming may involve methods either intensive or extensive, either expensive or inexpensive; and it must be practical and economical as well as scientific and thorough in order to be good farming. It is just as poor farming to go to too much expense as it

is to go to too little expense to accomplish a given result. These investigations show that the largest net profits have usually been obtained from crops raised by cultural methods involving a low cost of production rather than from high yields obtained under methods involving a high cost of production. Lessening the cost of production without proportionally lessening yields should therefore be given first consideration. In other words, extensive rather than intensive systems of farming should be followed.

(7) Different types of soil and different combinations of climatic conditions require different cultural methods and different combinations of crops to produce the most profitable results.

(8) The personality of the farmer and his family; the size, location, soil, and environment of the farm; market facilities and prices; the available capital, in cash, labor, or equipment, may any or all be determining factors in the problem of profitable dry farming in the Great Plains area.

(9) Dry farming in the Great Plains area, in common with all farming, to be successful must be systematized, and in order to accomplish this, some definite rotation of crops should be established. In planning such a rotation, due consideration should be given to all the factors here enumerated, as they apply to each particular farm and farmer. With these considerations clearly in mind, it is believed that no intelligent farmer will experience any great difficulty in adopting a system of crop rotation and farm organization that will be better adapted to his conditions than any that could be proposed by anyone less familiar with these conditions than is the farmer himself.

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A. C. TRUE, Director



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FARMERS' INSTITUTE WORK IN THE UNITED STATES IN 1914, AND NOTES ON AGRICULTURAL EXTENSION WORK IN FOREIGN COUNTRIES.

By J. M. STEDMAN, *Farmers' Institute Specialist.*

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INTRODUCTION.

In 1902 the United States Department of Agriculture gathered and compiled the first statistics regarding farmers' institute work in the United States and each succeeding year it has published a report of the Farmers' Institute Specialist showing the extent and progress of this movement. A review of these reports shows a continuous and steady growth in the number of institutes held each year and also in the attendance at the meetings. Until recently, the farmers' institute was the great and for 25 years practically the only organized movement for carrying on agricultural extension work. In the majority of States this work was originally under the direct control of the State departments of agriculture, but in other instances it was vested in the agricultural colleges. In either case the agricultural colleges were active in contributing to its support and have always furnished a large proportion of the institute lecturers. A few years ago the agricultural colleges began to devote an increasing amount of attention to farmers' institutes, and, later, to other phases of agricultural extension, and thus gradually become a major factor in the organized agricultural extension movement carried on by agencies other than the United States Department of Agriculture.

NOTE.—This publication is of interest to farmers' institutes and other agricultural extension workers in the United States and Canada.

Meanwhile a much broader system of agricultural extension work has been developing in the United States through the work of the United States Department of Agriculture and the State agricultural colleges. In consequence of the passage of the Smith-Lever Act closer cooperation between the department and the colleges has been effected and the organization and scope of the extension work of these institutions is being changed and strengthened in many ways. This is affecting the relations of the colleges with the farmers' institutes and will undoubtedly modify in a broad way the future character and status of farmers' institute work in this country.

This report covers the progress of farmers' institutes conducted by the States and the agricultural colleges during the fiscal year ended June 30, 1914, and also contains notes on agricultural extension work in foreign countries. It brings the history of farmers' institutes in the United States up to the time of the inauguration of the Smith-Lever Extension Act.

GENERAL STATUS OF FARMERS' INSTITUTES IN THE UNITED STATES.

Farmers' institute reports for the season of 1914 were received from all the States except Iowa, and institutes were held in all the States except Louisiana, Nevada, New Mexico, and Oklahoma.

The total number of sessions of farmers' institutes held during the year was 25,238, which is a 22 per cent increase over any previous year, while the total attendance at the same was 3,656,381, which is an increase of 26 per cent over that of any previous year. The total number of days devoted to institutes, exclusive of independent, round-up and special institutes, and railroad specials, was 52,354, while about 3,000 days additional were devoted to the other activities. The institute organization employed 759 regularly paid lecturers, in addition to which the agricultural colleges and experiment stations contributed the services of 528 members of their staffs a total of 7,142 days. Institutes especially for women were held in 13 States a total of 880 days and 5 States held special institutes for young people a total of 241 days.

The farmers institute organization conducts its work under many different forms, thus making it impossible to summarize all its activities under single heads. Hence, a clear idea of all its activities can only be had by consulting the detailed tables (pp. 16-21) accompanying this report. Thus, besides ordinary farmers' institute meetings, the farmers' institutes in 13 States conducted a total of 219 movable schools, lasting a total of 1,464 days, with a registered attendance of 112,498 different people. In 15 States they also carried on field demonstration meetings for which purpose 185 demon-

strators were employed a total of 40,084 days. Likewise, in 17 States, the institute organizations also conducted a total of 34 railroad specials which covered altogether 17,766 miles, during which 1,141 stops were made and lectures and demonstrations given a total of 474,906 different people.

It should be noted that the attendance at field demonstration meetings has not been recorded at all; that the attendance at movable schools contains no duplicates of individuals whatever, neither does the attendance at railroad specials, but that the total attendance at ordinary institute meetings represents the sum of the attendance at each half-day session and therefore may include an indeterminate number of duplicates of individuals in attendance at each institute if more than one session was held. The statistics of farmers' institutes has always been gathered and compiled in a similar manner, and hence a comparison of the activities of one year with those of another are rendered possible.

The total cost of conducting all forms of farmers' institutes was \$447,897.51, which is \$62,886.49 less than was spent last year. Since this reduction in the cost of institutes was accompanied with a large increase in the number of sessions and the people instructed, it clearly indicates a great improvement in the financial management of the institutes.

STATE FARMERS' INSTITUTE REPORTS.

Numerous items of interest showing the progress of the work, but which are incapable of tabulation appear in the reports of the directors. In order that these features may be known by the body of workers, the principal points presented are referred to in the following accounts under the names of the respective States:

ALABAMA.—At all institutes the boll weevil and live-stock industry were considered. A one week's round-up institute was held at the college of agriculture with an attendance of 716, which represented every county in the State.

ALASKA.—No institutes were held in Alaska. The agricultural resources of the Territory are as yet undeveloped, and the few farmers are so scattered that it is considered impractical to try to get them together. There is need for itinerant instruction.

ARIZONA.—Institutes were held in each county in the State. Three railroad instruction trains also covered a large part of the State. The following subjects were discussed at all institutes: Household helps, good roads, live stock on the farm, and dry farming. Boys' and girls' clubs, field demonstrations, and special institutes for women were new features on the institute program.

ARKANSAS.—No appropriation was made for farmers' institute work, but contributions amounting to \$1,421 from various sections of the State, together with some college funds made it possible to hold 20 farmers' institutes with an attendance of 1,610 and 24 movable schools with an attendance of 5,132, and to cooperate with three railroad-instruction trains. Twelve members of the college faculty gave 488 days of service. Hog cholera and Texas fever ticks were discussed at all institutes.

CALIFORNIA.—Owing to difference in climate, institutes were held every month in the year and in 41 of the 58 counties of the State. A feature of the work was the organization of young people's agricultural clubs. Forty members of the college and experiment station staff gave 300 days of service. Fourteen thousand five hundred students at educational institutions received instruction from the institute staff.

COLORADO.—No appropriation was available, but college funds and contributions for local sources made \$2,596 available, which was used in the conduct of 59 days of institutes. One instruction train made 31 stops with an attendance of 15,821.

CONNECTICUT.—Thirty-three lecturers addressed 50 farmers' institute sessions with an attendance of 2,750. An appropriation of \$700 was available.

DELAWARE.—Consolidation of rural schools was the leading topic at all of the 36 institutes held in Delaware. An instruction train carrying 11 lecturers, with exhibits, made 13 stops and was attended by 2,000 people.

FLORIDA.—The State appropriation was increased from \$7,500 to \$10,000. One hundred and thirty-two institutes, with an attendance of 15,676, were held. Twenty members of the agricultural college gave 692 days of service to farmers' institutes. Plans are being made for holding special institutes for farm women during the coming year.

GEORGIA.—Farmers'-institute work is closely related to other extension activities of the college. Twenty-five college and station men gave 1,426 days of service. The use of motion pictures was introduced into the institutes and proved a profitable feature. Seven movable schools enrolled 4,710.

IDAHO.—Farmers' institutes were held in every county in the State except one, which is wholly a mining county.

ILLINOIS.—The appropriation for farmers' institutes was increased from \$21,000 to \$33,179.50. This will make possible material enlargement in the scope of the work. Sixty-five lecturers were engaged in farmers'-institute work in the State during the year. An annual conference of farmers'-institute workers lasting for one week has proven a profitable feature in organizing the work.

INDIANA.—In Indiana 428 institutes were addressed by 50 State and 200 local speakers. Special attention was given to perfecting local organization, to the organizing of boys' and girls' school clubs, and to enlarging the usefulness of the institutes for farm women. Four conferences for farmers'-institute workers were held preceding the institute season.

IOWA.—No report has been received.

KANSAS.—The Kansas farmers' institutes are permanent organizations, with a total membership of about 15,000 farmers. In 1913 these organizations held an average of 3.38 monthly meetings in addition to the annual meeting, at which State lecturers are present. Eight women's institutes and eight young people's institutes, with an aggregate attendance of 8,721, were held.

KENTUCKY.—The live-stock industry was emphasized in all institutes during the year, also a larger place on the program was given to subjects of particular interest to women. Considerable attention was given to strengthening local institute organizations. Fruit-spraying demonstrations were a feature of a large number of the institutes.

LOUISIANA.—Farmers'-institute work in Louisiana is placed by statute under the direction of the commissioner of agriculture and immigration, but no appropriation has been available, though some work of similar nature has been done by the State college of agriculture and the experiment station.

MAINE.—Two institutes were held in each county in the State, at a cost of \$2,300. Sixty-four State lecturers, in addition to local speakers, addressed 73

institutes with 138 sessions. Also 248 special institutes of one to two days were held with granges, cow-testing associations, breeders' associations, and other organizations.

MARYLAND.—Fifty-six general institutes and nine women's institutes were held during the year, with a total attendance of 24,934. Three railroad instruction trains made 58 stops and carried 12 lecturers, who gave instruction in dairying, live stock, soil fertility, truck gardening, horticulture, corn, tobacco, alfalfa, and home economics. An extension department of the agricultural college has now been organized, and the institute work will become a phase of this department under a regular farmers'-institute director.

MASSACHUSETTS.—During the year the rules of the State board of agriculture were changed so as to require only one instead of three local institutes. This resulted in a number of places holding one big institute instead of a number of smaller ones. A continuous schedule for institutes increased effectiveness and reduced the per capita cost. Ninety-two State lecturers were engaged in institute work during the year.

MICHIGAN.—There was a substantial increase both in the number of institutes and in the attendance. Special attention was given to alfalfa in the institute program. Special institutes for farm women continued to be successful. Study clubs for women were also inaugurated. A round-up institute at the agricultural college had an attendance of 12,300.

MINNESOTA.—No farmers' institute organizations are maintained, but there are over 900 farmers' clubs which cooperate in the farmers' institute program. Special attention was given by the institute management to the organization and maintenance of these clubs. Institute workers gave 62 days' service as judges at agricultural fairs and 234 days' service as instructors in movable schools.

MISSISSIPPI.—Institutes were held in 69 counties in Mississippi. One railroad instruction train was run which gave instruction in the various phases of the live-stock industry. The entire institute force was in attendance at the Mississippi-Alabama Fair and the Mississippi State Fair, with an agricultural exhibit. Very effective work was done in promoting better agriculture.

MISSOURI.—Owing to a change of administration complete data for farmers' institute work is not available, but silage and alfalfa were discussed at 240 institutes. Two hundred pounds of ground limestone were furnished free to each farmer who applied to the State board of agriculture. A State-wide campaign for the use of home products was conducted and illustrated lectures were introduced into the institutes. Much agricultural literature was distributed.

MONTANA.—Institutes were conducted in each county in the State with a total attendance of 20,962. Twenty-one movable schools for men and six for women were held with a total attendance of 380. The county agents assisted greatly in increasing the efficiency of the institutes. Local leadership is given as the greatest need of the institutes in the State.

NEBRASKA.—Nebraska held institutes in 71 of its 92 counties. Twenty-eight movable schools, most of which were for women and young people, enrolled 2,532 persons. Short courses for women are being conducted during the summer months. A dairy train was also operated. County demonstrations, hog cholera, and dairying were discussed at a majority of the institutes.

NEVADA.—No farmers' institutes were held in Nevada during the year.

NEW HAMPSHIRE.—Farmers' institutes were held in every county in the State. The State institute law was revised to provide for the holding of short courses in agriculture, under the direction of the institute force. Illustrated lectures and demonstration work were introduced in the farmers' institutes.

NEW JERSEY.—Five thousand two hundred and twenty-nine dollars were used in conducting 52 general institutes and 16 special institutes with an aggregate attendance of 12,657. Seventeen members of the agricultural college and experiment station gave 204 days of service. A successful farmers' week was held at the agricultural college.

NEW MEXICO.—No institutes were held in New Mexico, but an extension department has been organized at the agricultural college, and it expects to organize a number of institutes during the coming year.

NEW YORK.—Institutes were held in all the counties of the State except those comprised in greater New York and one mountain county. One hundred and twenty-six special sessions for women were held with an attendance of 6,003. A successful feature of the work was sheets containing questions on the topic being discussed. The questions were numbered and the audience called for answers to whatever questions they were interested in. One hundred special institutes were held in cooperation with the granges and the other agricultural association meetings.

NORTH CAROLINA.—An association for the conduct of institutes for women was organized to hold monthly meetings. Eight institutes were held for negroes with a good attendance. Institutes were held in 98 of the 100 counties of the State.

NORTH DAKOTA.—A new feature of the institute work was the introduction of farm inspection work.

OHIO.—Institutes were held in each county in the State. A successful feature of the work was the holding of preliminary conferences with the officers of the farmers' institutes of each county with a member of the farmers' institute staff, at which time the people decided where institutes should be held and laid plans for conducting them. The total attendance at farmers' institutes was more than 110,000.

OKLAHOMA.—Owing to an unusual situation in the State no appropriation was made for farmers' institute work, though some work along this line has been done by the agricultural college.

OREGON.—Special sessions of general institutes were held for women. Many special agricultural lectures were also given to fairs, commercial clubs, women's clubs, improvement associations, and to other organizations throughout the State. The institute work is closely related to the extension work.

PENNSYLVANIA.—Institutes were held in each county in the State. The 10 county agents in this State gave three months of their time to farmers' institute work. In addition, 11 members of the agricultural college gave 55 days of service. One hundred and fifty-four State lecturers were employed. Two railroad trains gave instruction in dairying, poultry, horticulture, and home economics. Large use was made of illustrated lectures at all the institutes.

RHODE ISLAND.—Sixteen institutes were held at a cost of \$445. The institute staff also gave field demonstrations in the care of orchards and held an annual corn show and industrial contest for adult boys and girls.

SOUTH CAROLINA.—In South Carolina the institute season is during July and August. A new feature of the work during 1913 was the holding of institutes on the farm, using the stock and field crops as illustrative material. All the work of instruction is by members of the faculty of the agricultural college and by county demonstration agents in the various counties.

SOUTH DAKOTA.—In addition to holding institutes in every county in the State, movable schools were a prominent feature of the work. Fifty-two of these were held, one-half of which were for women, with a total attendance of 53,948. A railroad instruction train carried 15 lecturers and gave instruction

in alfalfa growing, hog cholera, and silo construction to 20,000 people. Ladies' auxiliaries to the farmers' institutes have been organized which, in the future, will hold institutes simultaneously with the regular institutes.

TENNESSEE.—Six thousand two hundred dollars was available for the holding of 126 institutes, including 27 for women.

TEXAS.—Three hundred and eighty-five thousand, four hundred and forty people received instruction from the institute force during the past year. Special attention at the institutes was given to dairying, silos, hogs, poultry, and other live stock, insects and plant diseases, orchards and gardening, and marketing. Two demonstration trains made 225 stops and were visited by 140,000 people.

UTAH.—In Utah the farmers' institute work is a part of the extension work of the college. Fourteen members of the college faculty gave 168 days of service and conducted 577 farmers' institutes. A railroad instruction train gave instruction in measurement and proper use of irrigation water, dairying, silo construction, and stock raising.

VERMONT.—Twenty-four general institutes with an attendance of 5,095 covered all the counties in the State except one, at a cost of \$592.45. Special lectures in agriculture were given at grange meetings, picnics, clubs, and other gatherings of farmers.

VIRGINIA.—One hundred and thirty-one farmers' institutes with an attendance of 20,650 were held in 100 counties of the State. In addition, a large number of lectures on agriculture were given at special meetings with an estimated attendance of 11,000. Soil improvement, alfalfa feeding, hog raising, and home improvements were discussed at all the institutes. Agricultural literature was also distributed at the meetings. Four railroad trains made 77 stops and gave instruction in live stock, fruit growing, seed improvement, tobacco culture, trucking, and home economics.

WASHINGTON.—The farmers' institute work is carried on by the regular extension staff of the college. Seventeen thousand five hundred dollars was available for agricultural extension. No figures are available as to what part of this was spent on farmers' institutes.

WEST VIRGINIA.—Two hundred and forty-four institutes, with 61 separate sessions for women, were held in 41 of the 55 counties of West Virginia. Thirty movable schools, 10 of which were for women, enrolled 1,354. The use of lime was discussed at all of the institutes, and demonstration work was also a feature of the meeting. Seven thousand five hundred dollars was expended for farmers' institute work.

WISCONSIN.—Wisconsin held institutes in 68 of the 71 counties in the State. Special institutes in hog cholera and alfalfa were conducted, also normal institutes for teachers. Forty two-day institutes for women enrolled a large attendance. A railroad instruction train was run in cooperation with the Live Stock Breeders' Association of the State and gave instruction in dairying, alfalfa, and silage, hogs, sheep, and beef cattle industry.

WYOMING.—Wyoming has no department of farmers' institutes, but farmers' institutes are conducted by the officers of the college and experiment station. Silo construction and home-economics subjects were features of the institutes held during the past year.

AGRICULTURAL EXTENSION WORK IN FOREIGN COUNTRIES.

The experience of foreign nations in conducting agricultural extension work is of special interest to those in charge of similar work

in the United States, since this method of fostering agriculture has been in successful operation for many years in the older countries. The following notes, which are incapable of tabulation, were translated and abstracted from current foreign journals received since the last report was written:

FRANCE.—Considerable emphasis is given to what is called the feminist movement in agriculture in France.¹ In addition to the extension of instruction in agriculture for girls in the regular schools, clubs of farm girls and women are becoming more and more numerous. The great agricultural societies are opening their ranks to female collaborators. Everywhere rapid progress is being made in the technical and general education of the women who live on the farm. In 1914 there were 38 movable schools giving housekeeping instruction to 2,800 young girls. The program of these schools is arranged according to the needs of the region in which they are held. In addition to housekeeping subjects, the care of milk, the making of butter, and aviculture are taught. When a course is finished in a community, the teachers assemble the mothers and farm women for evening courses and lectures.

Clubs of farm women are organizing institutes for farm women along the lines of those conducted in Canada and the United States. Also numerous competitions for farm women are held in aviculture and other lines of agriculture in which prizes valued at from \$70 to \$200 are awarded.

The women's section of the Society of French Agriculturists is now two years old, having been founded in 1912 to interest women in country life and to enable them to work out more efficiently their economic, moral, and social education. The first work of the section was to conduct a survey to ascertain the condition and needs of farm women, and its inquiries show clearly the gravity of the rural crisis for which the "distaste of women for rural life" is largely responsible. This survey revealed the growing distaste of the young country woman for farm life; her extreme ignorance of housekeeping and farm work; her loneliness and her desire for recreation; and the need for her mental improvement. The section has founded five traveling housekeeping schools. Many clubs of farm women which were among the first independently established in France have associated themselves with the section.

The National Society for the Encouragement of Agriculture, through a happy innovation, has just begun to allow female competition. In organizing the congress of the farm home, an effort has been made to show clearly, by the choice of the subject as well as by the personnel of the committee of organization, that the rural crisis is worthy of consideration from the female point of view.

BRAZIL.²—Brazil has conducted its first agricultural institute train. The Argentine Central Railway, with the cooperation of a provincial agriculturist fitted up two passenger coaches, one for lecture purposes and one for an exhibition car.

The conferences and demonstrations are held in the rural centers on Sundays and holidays. They are thus carried on without taking the farmers from their work. When extraordinary occurrences, such as sudden plagues and the like, make the work of the school necessary, it is moved to the place indicated to give advice and practical teaching as the case may demand.

¹ Vie Agr. et Rurale, 3 (1914), No. 23, pp. 625-628; Bul. Soc. Agr. France, 75 (1914), No. 1, Sup., p. 248.

² Bol. Min Agr. Indus. e Com. [Brazil], 2 (1913), No. 2, pp. 104-107.

The work of the train has been so satisfactory that it has been decided to make it a permanent institution for the following purposes:

Holding public conferences on agriculture in rural centers; answering inquiries, verbal or written, on subjects of interest to farmers; distributing agricultural literature; making demonstrations of agricultural machinery; visiting agricultural expositions; cooperating in the improvement of animal industry; cooperating in the diffusion and knowledge of laws relating to hygiene and labor for farmers, as well as diseases of plants and animals; furthering the establishment of societies and cooperative associations for agricultural improvement; and inspection of public and private agricultural estates.

AUSTRIA.—A regular agricultural school education is available only for a limited number of prospective farmers in Austria, therefore, other methods of disseminating agricultural instruction are necessary, such as traveling lectureships and special courses. Lectures are given by the teachers in the regular agricultural schools and by traveling lecturers appointed especially for this purpose. They keep in close touch with the rural population and are expected to give personal attention and advice to individual farmers in their territory. They also hold courses which last for several days in order to instruct farmers in certain branches of agriculture, such as dairying, live stock, poultry keeping, fruit growing, etc. Teachers in the agricultural schools also hold such courses during vacation either at the school or elsewhere. Lectures in cooking and domestic economy are also given for the women and girls.

In Upper Austria three itinerant teachers in cooking and housekeeping are employed, and they have conducted 47 movable schools in housekeeping for 564 girls. The length of the course is six weeks. The number in a course is limited to 12 girls, who must be over 14 years of age.

The courses are under the direction of the Royal Agricultural Society, in cooperation with a local society or board, which must furnish the meeting place and guarantee an enrollment of 12 girls and their tuition fee.

In these courses are taught buying of food materials; the preparing of foods; the preserving of provisions; setting and waiting on the table; washing dishes and linen and house cleaning; making recipes; and estimating the cost of food. The management of the house and the care of clothing are also taught. Instruction is likewise given in the care of the health, feeding children, care of the sick, mending, patching, and darning. There is also instruction in feeding domestic animals, the care of the dairy, the raising of poultry, and in the culture of fruit, vegetables, and flowers.

Two women are chosen to supervise each cooking course and hold themselves in readiness to assist the teacher, keeping her informed as to the proper markets for provisions, and discussing with her the arrangement of the daily work, the regulation of the larder and of the kitchen, and to give necessary help to the pupils.

PRUSSIA.—In 1912 there were in Prussia¹ 250 rural traveling housekeeping schools in full working order, divided among 243 districts (Landkreise).

A total of 817 courses were held, as against 564 in the previous year. The number of the eight weeks' courses has risen from 407 to 638, the number longer than eight weeks from 67 to 103, while the courses of less than eight weeks' duration have fallen from 90 to 76. The 817 courses were attended by 13,581 girls and young women who had left school, an average of 21.3 per course.

Of the 250 schools 168 were supported by the District Communal Association, 5 of them being under the supervision of women's unions, 65 were entirely man-

¹Zeitschr. f. ländl. Fortbild. Schulw. Preussen, 5 (1913), No. 2, pp. 47-61.

aged by women's unions, and 17 by private individuals and others. The whole maintenance cost amounted to \$146,520.

GERMANY.—The West German Agricultural Board, after a tour of inspection of the rural itinerant home economics schools of the region under its jurisdiction, reports¹ that the instruction given by these schools is confined very largely to needlework and to cooking, and that instruction even in elementary agriculture is given to only a very limited extent. The board deprecates this situation and points out the necessity for teaching agriculture to at least a limited extent in the housekeeping schools, emphasizing the fact that this is particularly necessary in the flat sections of west Germany, where the farms are usually small and the wives and daughters have charge of the stable, yard, and garden, as well as the housekeeping, and where an income can be assured only when all of the farm work is done with expert knowledge. The board therefore holds that the housekeeping courses will be more useful if the needlework is limited to mending, darning, and repairing, and to the making of simple linen articles, and the time thus saved devoted to instruction in some of the simpler farm operations. Another argument in favor of such agricultural instruction is that it might tend to create a different attitude toward farm life among the young women of the region who at present show very little interest in agriculture and prefer to marry those engaged in other occupations.

The insufficient agricultural instruction is thought to be due in many cases to lack of knowledge of farm life and farm work on the part of the teachers in the schools. It was also found that the teachers were frequently unfamiliar with the household and farming conditions of those taking the courses. It is stated that the plan of giving agricultural instruction in the home economics schools as recommended by the board has been approved by the minister of agriculture and appropriations will be granted to these schools only on condition that this plan is followed.

BELGIUM.—Movable housekeeping schools were established in Belgium² in 1890, in which year 13 of these schools were started. Over 6,000 girls have received diplomas in these schools since their organization. The primary design of the school was to elevate the national dairy industry and to teach better methods of utilizing milk and of making butter and cheese. The length of the session is four months, and the schools are moved two or three times a year from one community to another. Courses are now offered in agronomy, zoology, dairying, cheese making, domestic economy, and bookkeeping.

A movable school is established at the request of the community or an agricultural association. The budget of the school amounts to about \$500 for a session of four months. This sum is borne by the State, the Province, and the agricultural societies. The instruction is given without expense to the students.

The instruction is theoretical and practical. The courses are conducted six days a week. Two hours are devoted to theory and three to practical work. All the pupils are day scholars. The maximum number of pupils admitted to the school does not exceed 20. To be admitted to the school, girls must be 15 years of age, must have had good primary instruction, as shown by a certificate, and must be physically able to do the work.

The teaching personnel is composed of a principal, who has charge of the courses in agronomy; he also attends to the organization of the school. Two female teachers living at the school have charge of the courses in domestic economy, dairying, cheese making, and bookkeeping, and they direct the practical

¹ *Ztschr. Landw. Kammer Schlesien*, 18 (1914), No. 8, p. 343.

² *Rev. Gen. Agron.*, n. ser., 9 (1914), No. 2, p. 84.

work of the pupils. The teachers have a fixed salary paid by the State. When the school is not in session they hold conferences or public courses for farmers' wives.

All of the schools are supplied with suitable equipment for practical instruction, such as churns, separators, refrigerators, cheese-making utensils, cooking utensils, washing machines, sewing machines, etc. At the end of each session an examination is held in the different branches taught.

The success of movable schools is generally much greater than that of permanent schools, because the small and middle class farmers can not easily send their children to school for one or two years. The temporary schools, which last only four months, come to the pupils in their homes and are, therefore, more easily established.

ARGENTINA.—Agriculture in Argentina¹ is handicapped because those who follow it are frequently ignorant of its most fundamental principles, many of them being immigrants who have recently taken up farm work to meet the necessities of life and are not familiar with their new conditions. This explains the important place that extension instruction occupies in the agricultural development of the country.

The extension service is in direct charge of the regional agronomists, who at present (1912) number 20. They expedite their work by means of consultations, temporary courses, inspections, competitions, and expositions.

The following table gives a summary of the work of the regional agronomist in 1912:

Summary of work of regional agronomist, 1912.

Date of taking charge.	Location of regional agronomists.	Consultations.		Conferences.	Experimental fields.	Temporary courses.
		Verbal.	Written.			
1912.....	Mercedes.....	1,960	155	63	10	.....
May.....	Olavarría.....	505	286	12	9	.....
April.....	Campana.....	20	10	5	0	.....
1912.....	Entre Ríos.....	589	383	38	20	.....
1912.....	Corrientes.....	392	83	6	5	.....
October.....	Chaco and Formosa.....	.....	.....	.....	.....	.....
1913.....	Posadas.....	.....	.....	.....	.....	.....
January.....	Tucumán.....	.....	.....	.....	.....	.....
November.....	Jujuy.....	187	48	4	9	1
1912.....	Santiago del Estero.....	122	62	.....	8	.....
May.....	Catamarca and La Rioja.....	106	42	2	5	.....
July.....	Mendoza.....	.....	.....	.....	.....	.....
November.....	San Luis.....	4,747	977	14	70	2
1912.....	Córdoba.....	220	6	6	10	.....
June.....	San Juan.....	185	29	.....	11	.....
May.....	Rafaela.....	8	2	.....	.....	.....
June.....	Rosario.....	124	5	5	.....	.....
May.....	Pampa.....	105	4	5	11	.....
June.....	Rio Negro.....	57	.....	.....	.....	.....
December.....	Bahía Blanca.....	110	46	3	6	.....
1912.....	Total.....	9,427	2,138	163	173	3

The agronomists of Tucumán, Posadas, Chaco and Formosa, Mendoza, and Rio Negro took charge at the end of 1912, devoting all their time to surveying their respective districts to find out their real needs. The vast and complex duties of the regional agronomists has not allowed them to give much time to developing extension courses, but the General Board of Agricultural Instruction is contemplating remedying this by the appointment of special teachers under the supervision of the agronomist. Agricultural instruction has been introduced into the army.

¹ Min. Agr. Argentina, Mem. Cong. Nac. (1912), pp. 33-36.

ENGLAND.—The Board of Agriculture and Fisheries¹ has made arrangements in England and Wales for providing technical instruction in agriculture to small holders. It appears that in spite of recent advances there is still much room for the small holder to improve his condition with the help of suitable instruction.

Out of a total of 435,700 holdings in England and Wales above 1 acre, 292,400 are under 50 acres, while in addition there are over 118,000 allotments under 1 acre belonging to local authorities apart from a large number of allotments leased by private landowners. Thus there is an extensive field of work for the teacher, and it must be remembered that of all classes of the rural population the small holder and rural laborer have the least opportunity of obtaining instruction and skilled advice.

Small holders and allotment holders are usually to be found in groups or colonies, and these afford a convenient center for organized day and evening classes, and for courses in such subjects as horticulture, poultry keeping, and dairying. Such a colony is also a most appropriate center for demonstration fields or plots to illustrate the best methods of growing and manuring market garden crops, fruit, etc. These demonstrations are used by the instructors to introduce crops not usually cultivated by the holders, and when well managed are of greater use in educating the small holders than class-room instruction.

CANADA.—In Canada² women's institutes have powerfully contributed to improve the position of farm women, while also raising their intellectual level, and justify the interest they have aroused, even beyond the limits of the country in which they had their origin. They have been copied with excellent results, especially in the United States, where similar associations have been very successful.

Women's institutes were first founded in Ontario, and their development has been most remarkable. At present there are 800 of them, with about 25,000 members. In 1912-13 lecturers were sent to 1,377 meetings, and 6,204 meetings were held without the assistance of outside lecturers. In 1912-13, 1,667 persons attended the demonstration lecture courses.

In Manitoba these institutes are called home economics societies. Their progress has been very rapid recently. The department of agriculture has directed the work and appointed special inspectors and lecturers to travel through the Province, organize new societies, give courses of instruction in those already existing, and supervise their work.

There are 35 women's institutes in British Columbia with a membership of over 2,000.

In New Brunswick there are 1,000 members in 41 local women's institutes.

In Saskatchewan and Alberta domestic-science courses have been held, though not directly in connection with women's institutes.

ITALY.—In Italy³ a considerable number of so-called itinerant chairs of instruction in agriculture and viticulture are scattered throughout the Kingdom. They are under the oversight of the ministry of agriculture and for the most part are autonomous; that is, they are founded and administered by local bodies of interested persons and are maintained by the communes and Provinces and by the State. Each of these have their own subordinate institutions (sections).

¹ Jour. Bd. Agr. [London], 21 (1914), No. 6, pp. 571, 572.

² Internat. Inst. Agr. [Rome], Mo. Bul. Econ. and Soc. Intel., 5 (1914), No. 6, pp. 17-19.

³ Land u. Forstw. Unterrichts-Ztg., 27 (1913), No. 1-2, pp. 125, 126.

The chairs of instruction are usually provided with professional agricultural teachers having charge of the itinerant instruction in the adjoining communes. About 80 communes are assigned, on the average, to one itinerant teacher.

The object of itinerant instruction is to disseminate agricultural knowledge through immediate contact with the rural population by holding lectures and conferences.

The itinerant teachers are also bureaus of information on all agricultural questions.

The number of itinerant chairs of instruction is 94, that of the sections 86.

The total expenses for itinerant instruction in 1910 amounted to \$50,000.

ROUMANIA.—In Roumania¹ the itinerant agricultural teacher is usually a national-school teacher with practical agricultural knowledge, besides a knowledge of gardening and orcharding. He is allowed a seven months' furlough yearly, during which time he is obliged to visit a certain number of rural national schools which have school gardens or experimental fields. During his stay at the school the teachers and the advanced pupils work one or two days under his superintendence and according to his direction. After the itinerant teacher has visited all the schools in the district assigned to him, he goes back to the first one to assist in a new line of work. He controls the results obtained and records his observations in an inspection book. In this way a single itinerant teacher can give practical agricultural instruction to 10 or 12 schools, from which not only the schools but the teachers derive advantage.

BAVARIA.—In Bavaria² itinerant instruction has been introduced, and it is primarily the duty of the royal agricultural teachers appointed as directors and head teachers in the winter agricultural schools to supervise and further it. By establishing winter schools and filling the position of directors with properly trained permanent teachers competent persons have been provided, who are better able to supervise itinerant instruction. There are now in Bavaria 40 agricultural itinerant teachers, highly qualified in the subject of agriculture. With a small circuit it is possible for the itinerant teacher to get in close touch with the farmers of the district, and not simply to be present sporadically in this and that place for the purpose of delivering a one-hour lecture. Lecturing is only a small part of the work of the itinerant teachers. Their principal duty is to travel regularly over their districts, remain in a community long enough to obtain definite information, enter into agreement with the authorities, suggest improvements, undertake experiments, and aid those interested by personal advice.

The itinerant teachers keep in close touch with practical fertilizer and cultivation experiments on the farmers' fields, in order to demonstrate the advantages of proper fertilization, the selection of good seed, the adaptability of certain kinds of plants to regions in question, and to encourage imitation; in the same way new machines and tools are introduced.

Courses of considerable duration—perhaps three to eight days—do more good than lectures, and great importance is attached to them. Such courses are given for every branch of farming, and have hitherto been principally organized and directed by associations. In order that the work of the societies may be made as practical as possible in all regions, the district officers encourage the holding of housekeeping courses.

BOSNIA AND HERZEGOVINA.—In Bosnia and Herzegovina³ itinerant teachers travel over the entire agricultural districts, chiefly for the purpose of giving

¹ Land u. Forstw. Unterrichts-Ztg., 18 (1904), No. 3-4, pp. 212, 213.

² Land u. Forstw. Unterrichts-Ztg., 18 (1904), No. 3-4, pp. 204, 205.

³ Land u. Forstw. Unterrichts-Ztg., 25 (1911), No. 1, pp. 119-121.

popular agricultural lectures and practical demonstrations for instructing the farmers in proper farm management as well as making suggestions for the advancement of agriculture.

The agricultural societies are exceedingly active and successful in all agricultural lines. They have thus obtained very satisfactory results in agriculture by encouraging the members to fall plow, to properly fertilize, as well as to use modern implements of cultivation, and to establish model farms. In the advancement of cattle raising they have rendered great service by providing breeding stations and by their influence on better feeding and care of animals. The establishment of district granaries is also due to the efforts of the itinerant agricultural teachers.

Besides the itinerant teachers, the agricultural officials take part in the technical instruction of the rural population to a considerable extent. This is particularly true of the officers who are specially appointed for instructing the farmers in the proper cultivation of sugar beets. To each of these officers a special district is assigned and he is obliged to give popular lectures throughout his district. During these lectures the work of the season is freely discussed. These officers have rendered a valuable service to agriculture which should not be underrated.

OFFICIALS IN CHARGE OF FARMERS' INSTITUTE WORK IN THE UNITED STATES.

ALABAMA.—C. A. Cary, Alabama Polytechnic Institute, Auburn.

ALASKA.—C. C. Georgeson, Agricultural Experiment Station, Sitka.

ARIZONA.—S. F. Morse, director of extension, Tucson.

ARKANSAS.—W. C. Lasseter, director of extension, Fayetteville.

CALIFORNIA.—W. T. Clarke, superintendent of farmers' institutes, Berkeley.

COLORADO.—C. A. Lory, acting director of farmers' institutes, Fort Collins.

CONNECTICUT.—H. J. Baker, in charge of farmers' institutes, Storrs.

DELAWARE.—Wesley Webb, secretary State board of agriculture, Dover.

FLORIDA.—P. H. Rolfs, director of extension and superintendent of farmers' institutes, Gainesville.

GEORGIA.—A. M. Soule, president and acting director extension State college of agriculture, Athens.

HAWAII.—William Weinrich, jr., secretary and treasurer farmers' institutes, Honolulu.

IDAHO.—O. D. Center, director extension work, Boise.

ILLINOIS.—H. A. McKeene, secretary Illinois farmers' institutes, Springfield.

INDIANA.—W. C. Latta, farmers' institute specialist, Lafayette.

IOWA.—A. R. Corey, secretary State board of agriculture, Des Moines.

KANSAS.—Edw. C. Johnson, superintendent of farmers' institutes, Manhattan.

KENTUCKY.—Harry McCarty, director of institutes, Frankfort.

LOUISIANA.—W. R. Dodson, director of extension, Baton Rouge.

MAINE.—J. A. Roberts, commissioner of agriculture, Augusta.

MARYLAND.—R. S. Hill, director of farmers' institutes, Upper Marlboro.

MASSACHUSETTS.—Wilfrid Wheeler, secretary State board of agriculture, Boston.

MICHIGAN.—L. R. Taft, superintendent of farmers' institutes, East Lansing.

MINNESOTA.—A. D. Wilson, director of farmers' institutes, University Farm, St. Paul.

MISSISSIPPI.—R. H. Pate, director of farmers' institutes, Agricultural College.

MISSOURI.—Jewell Mayes, secretary State board of agriculture, Columbia.

MONTANA.—F. S. Cooley, superintendent of farmers' institutes, Bozeman.

- NEBRASKA.—C. W. Pugsley, director agricultural extension service, Lincoln.
- NEVADA.—C. S. Knight, director of extension.
- NEW HAMPSHIRE.—Andrew L. Felker, commissioner of agriculture, Concord.
- NEW JERSEY.—Alexis L. Clark, director of farmers' institutes, New Brunswick.
- NEW MEXICO.—A. C. Cooley, director of farmers' institutes, State College.
- NEW YORK.—Edw. Van Alstyne, director bureau of farmers' institutes, Albany.
- NORTH CAROLINA.—T. B. Parker, director of farmers' institutes, Raleigh.
- NORTH DAKOTA.—G. W. Randlett, superintendent of farmers' institutes, Agricultural College.
- OHIO.—A. P. Sandles, president agricultural commission, Columbus.
- OKLAHOMA.—W. D. Bentley, director of extension, Stillwater.
- OREGON.—R. D. Hetzel, director extension work, Corvallis.
- PENNSYLVANIA.—A. L. Martin, director of farmers' institutes, Harrisburg.
- PORTO RICO.—R. S. Garwood, dean agricultural college, Mayaguez.
- RHODE ISLAND.—John J. Dunn, secretary State board of agriculture, Providence.
- SOUTH CAROLINA.—W. W. Long, State agent and director of extension, Clemson College.
- SOUTH DAKOTA.—H. H. Stoner, superintendent of farmers' institutes, Highmore.
- TENNESSEE.—T. F. Peck, commissioner of agriculture, Nashville.
- TEXAS.—J. W. Neill, director of institutes, Austin.
- UTAH.—E. G. Peterson, director agricultural extension division, Logan.
- VERMONT.—Elbert S. Brigham, commissioner of agriculture, St. Albans.
- VIRGINIA.—J. J. Owen, director of institutes, Richmond.
- WASHINGTON.—J. A. Tormey, director extension division, Pullman.
- WEST VIRGINIA.—C. R. Titlow, director of agricultural extension, Morgantown.
- WISCONSIN.—C. P. Norgord, director of farmers' institutes, Madison.
- WYOMING.—H. G. Knight, director agricultural experiment station, Laramie.

	20		1				21		22		46		2,500					
New Hampshire.....	48		5				53		58		150		10,257					54
New Jersey.....																		68
New Mexico ¹																		
New York.....	324		40				370		422		1,190		102,594					86
North Carolina.....	280				1		261		263		514	500	23,007					57
North Dakota.....	25		31				56		87		182		16,868					93
Ohio.....			414				414		828		2,070		486,450					235
Oklahoma ¹																		
Oregon.....	265		2				297		299		632		50,291					80
Pennsylvania.....	23		193				225		436		1,103		174,260					158
Porto Rico ¹																		
Rhode Island.....	14		1				15		16		20		2,400					120
South Carolina.....	105						105		105		210		35,000					167
South Dakota.....	95	141	143				238	141	381	141	626	141	54,734	15,740				192
Tennessee.....	45						48	3	54	9	99	27	20,000	3,000				183
Texas.....	1,048		211	13			1,071		211	1,104	211	1,315	385,440					293
Utah.....	406	136	11	6			423	154	446	184	571	204	36,977	8,004				54
Vermont.....	24						24		24		48		5,095					106
Virginia.....	131						131		131		262		20,650					79
Washington.....	15		29				72		157		421		47,306					113
West Virginia.....	14		115				129		244		552		50,771					92
Wisconsin.....	15		110	40			125	40	235	80	580		111,773					193
Wyoming.....	19	3	19				40	3	63	3	122	3	8,393	60	85			67
Total.....	5,554	724	1,791	128			7,740	880	9,601	1,064	19,431	1,451	2,964,769	78,237	7,145			

² No report.¹ No institutes.

Financial statistics of the farmers' institutes for the year ended June 30, 1914.

State or Territory.	Funds appropriated.		Cost of institutes.		Appropriation for the season 1915.
	By the State.	By the college and received from other sources.	Total cost.	Cost per session.	
Alabama.....	\$600.00	\$800.00	\$1,400.00	\$31.11	\$600.00
Alaska ¹					
Arizona.....	4,400.00	408.30	4,808.30	85.86	4,400.00
Arkansas.....		1,421.10	1,421.10	118.42	
California.....	10,000.00		10,000.00	17.54	10,000.00
Colorado.....		2,596.00	2,596.00	20.60	
Connecticut.....			916.95	18.34	
Delaware.....	1,000.00	150.00	1,150.00	13.37	1,000.00
Florida.....	10,000.00		10,000.00	50.76	10,000.00
Georgia.....	2,500.00		2,500.00	11.47	
Hawaii ²					
Idaho.....					
Illinois.....	24,500.00	8,679.50	33,179.50	38.66	24,500.00
Indiana.....	10,050.00	12,000.00	22,050.00	17.42	10,000.00
Iowa ²					
Kansas.....	13,500.00	2,000.00	15,500.00	14.54	14,000.00
Kentucky.....	7,025.82		8,525.82	19.67	
Louisiana ¹					
Maine.....	2,300.00	500.00	2,800.00	19.45	
Maryland.....	6,000.00		5,345.00	29.53	6,000.00
Massachusetts.....	6,000.00		2,076.91	13.57	6,000.00
Michigan.....	8,500.00		12,000.00	8.10	8,500.00
Minnesota.....	23,000.00	3,265.00	26,244.73	76.74	23,000.00
Mississippi.....	7,500.00	2,000.00	9,500.00	17.46	9,000.00
Missouri.....	8,500.00		8,500.00	27.86	
Montana.....	10,000.00		10,000.00	48.31	
Nebraska.....	25,000.00		25,000.00	46.73	25,000.00
Nevada ¹					
New Hampshire.....	1,200.00		1,186.00	25.78	2,000.00
New Jersey.....	4,229.00	1,200.00	5,429.00	36.19	3,500.00
New Mexico ¹					
New York.....	20,000.00	19,760.52	39,760.52	33.41	25,000.00
North Carolina.....	12,000.00	2,000.00	13,500.00	13.31	12,000.00
North Dakota.....	6,000.00	915.00	5,376.00	29.54	6,000.00
Ohio.....	26,400.00	4,472.95	30,872.95	14.92	26,400.00
Oklahoma ¹					
Oregon.....	2,500.00		6,700.00	10.60	2,500.00
Pennsylvania.....	22,500.00	4,000.00	26,500.00	24.03	22,500.00
Porto Rico ¹					
Rhode Island.....	700.00	200.00	645.31	32.26	
South Carolina.....	2,500.00		2,200.00	10.47	
South Dakota.....	20,000.00		20,000.00	26.08	20,000.00
Tennessee.....	5,000.00	1,200.00	5,000.00	39.68	5,000.00
Texas.....	17,500.00		16,903.97	12.85	17,500.00
Utah.....	10,000.00		10,000.00	11.98	10,000.00
Vermont.....	592.45		1,192.45	24.84	600.00
Virginia.....	5,000.00		5,000.00	19.09	5,000.00
Washington.....	17,500.00		8,750.00	41.57	25,000.00
West Virginia.....	7,317.00		9,317.00	16.88	7,500.00
Wisconsin.....	20,000.00		20,000.00	34.48	20,000.00
Wyoming.....	1,050.00	750.00	2,050.00	16.14	1,050.00
Total.....	382,364.27	67,518.37	447,897.51	20.43	363,550.00

¹ No institutes.² No report.

Number of lecturers employed by the State directors of farmers' institutes and reports of proceedings published for the year ended June 30, 1914.

State or Territory.	Total number of lecturers on the State force.	Number of members of agricultural college and experiment station staffs engaged in institute work.	Number of days contributed to institute work by agricultural college and experiment station lecturers.	Number of State lecturers giving agricultural instruction at—				Reports of proceedings.	
				Teachers' institutes.	High schools.	Normal schools.	Common schools.	Published.	Number of copies.
Alabama.....								No.....	
Alaska ¹								Yes.....	
Arizona.....	19	15	356	2	1		1	Yes.....	
Arkansas.....	15	12	488	15	5			No.....	
California.....	125	40	300	8	10	1	24	Yes.....	20,000
Colorado.....	17	17	120	3				No.....	
Connecticut.....	33							No.....	
Delaware.....	22	6	32					No.....	
Florida.....	18	20	692	2		2	6	Yes.....	20,000
Georgia.....	25	25	1,426	5				Yes.....	2,500
Hawaii ²									
Idaho.....		20							
Illinois.....	65							Yes.....	50,000
Indiana.....	50	9	49					Yes.....	1,000
Iowa ²									
Kansas.....	38	14	163	9	156			No.....	
Kentucky.....	10		10					Yes.....	5,000
Louisiana ¹									
Maine.....	64	10	27					No.....	
Maryland.....	20	11	50					No.....	
Massachusetts.....	93	22	37		5			No.....	
Michigan.....	42	6	20					Yes.....	12,500
Minnesota.....	24							Yes.....	50,000
Mississippi.....	19	12	130	3	3	5	3	No.....	
Missouri.....								No.....	
Montana.....	29	18		3	19			No.....	
Nebraska.....	65	18	89		6		6	No.....	
Nevada ¹									
New Hampshire.....	10	7	14					Yes.....	
New Jersey.....	41	17	204	1	1	1		No.....	
New Mexico ¹									
New York.....	97	39	98					Yes.....	10,000
North Carolina.....	52	15	286					Yes.....	35,000
North Dakota.....								Yes.....	10,000
Ohio.....	43	20	192					Yes.....	
Oklahoma ¹									
Oregon.....	11	51	1,052	1	6			No.....	
Pennsylvania.....	54	11	55					No.....	
Porto Rico ¹									
Rhode Island.....	15	4	4			1	1	No.....	
South Carolina.....	12							No.....	
South Dakota.....	15							No.....	
Tennessee.....	15							Yes.....	3,000
Texas.....	16	20	150	50	135	5	158	No.....	
Utah.....	15	14	168					No.....	
Vermont.....	5	1	2					No.....	
Virginia.....								No.....	
Washington.....	20	31	650					No.....	
West Virginia.....	38	13	156	2	1	11	1	Yes.....	
Wisconsin.....	16	5	19					Yes.....	60,000
Wyoming.....	9	5	103	3				No.....	
Total.....	1,287	528	7,142	107	348	26	200		279,000

¹ No Institutes.

² No report.

[illegible]

¹ No institutes.

² No report.



BULLETIN No. 270



Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

July 29, 1915.

CEREAL EXPERIMENTS AT THE WILLISTON SUBSTATION.¹

By F. RAY BABCOCK,

Scientific Assistant, Office of Cereal Investigations.

(In cooperation with the North Dakota Agricultural Experiment Station.)

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INTRODUCTION.

The experiments with cereals at the Williston substation in North Dakota have been conducted cooperatively since 1908 by the Office of Cereal Investigations of the Bureau of Plant Industry and the North Dakota Agricultural Experiment Station. The memorandum of understanding between the two parties specifies that—

The objects of these cooperative investigations shall be (1) to improve the wheat industry of the northern Plains region by discovering or producing varieties better than those now grown, especially with regard to nitrogen content, yield, earliness, drought resistance, etc.; (2) to conduct similar experiments with oats, barley, and other cereals when it may be desirable; and (3) to determine the effect of changes of environment upon the growth of cereals, particularly the composition of the wheat kernel.

¹ The Williston substation was established in 1908 by the North Dakota Agricultural Experiment Station and has since been operated as one of the several "subexperiment stations" located at various points in the State. President J. H. Worst, of the North Dakota Agricultural College, was director of the State station from the time the Williston substation was established until January 1, 1914, when Mr. Thomas P. Cooper was appointed director. Prof. J. H. Shepperd has been vice director of the station during the entire period. Mr. E. G. Schollander was superintendent of the Williston substation from the first year of its operation, 1908, until April 1, 1914. Upon his resignation, Mr. Charles H. Ruzicka took charge. In 1908 the writer was appointed special agent in the Office of Cereal Investigations to take charge of the cooperative cereal work and in 1914 was appointed scientific assistant.

NOTE.—This bulletin presents the results of varietal tests with cereals which have been conducted at Williston, N. Dak., from 1908 to 1914, in cooperation with the North Dakota Agricultural Experiment Station. The subject is of interest to experimenters throughout the Great Plains area, and especially in western North Dakota and eastern Montana.

Data on the cooperative cereal work are included in each of the several annual reports published by the Williston substation.¹ This bulletin summarizes the cooperative cereal experiments for a period covering seven years, and such conclusions as are warranted are presented.

DESCRIPTION OF THE SUBSTATION.

The results obtained at the Williston substation are applicable only to portions of North Dakota and eastern Montana. Conditions very similar to those at Williston occur in all of North Dakota lying west of the one hundred and first meridian and the Missouri River, and in the eastern portion of Valley, Custer, and Dawson Counties, Montana. The one hundred and first meridian runs through Bottineau, McHenry, and McLean Counties in North Dakota.

To determine just how far the results obtained at Williston are applicable to other parts of the district, it is necessary to consider the variability of the climate and other conditions. In order that such comparisons may be made, a detailed description of the Williston substation is here given.

LOCATION.

The Williston substation is located about one-half mile north of the city of Williston and $1\frac{1}{2}$ miles north of the Missouri River, in the south-central part of Williams County. It comprises 160 acres, of which a part is creek-bottom flat and the remainder level or rolling bench land above the creek bottom. The elevation is approximately 1,900 feet above sea level.

The Little Muddy Creek drains the locality to the north for several miles, borders the substation on the east, and empties into the Missouri River. On both sides of this creek is an alluvial valley, varying in width from less than a mile to more than 5 miles.

Outside of this valley there are two extensive types of topography, as well as two soil types: (1) The gently rolling or nearly level areas of good agricultural land of the soil type known as Williams loam and (2) the sharply rolling hills along the streams, composed of a stony, rock-strewn soil known as Williams stony loam.

Until within the last few years all of western North Dakota and eastern Montana was a range country. Now, however, there are no large ranches except in rough areas where the raising of crops is difficult. The new settlers raise wheat almost exclusively during the first few years. After that they gradually adopt a system of more diversified farming, including the growing of other small grains, corn, and legumes, and the keeping of live stock.

¹ North Dakota Agricultural Experiment Station, Williston Subexperiment Station, Annual Reports, 1908 to 1913.

PHYSICAL FACTORS.

A summary of crop yields for a series of years should be accompanied by a statement of the physical factors that influence crop production. The most important physical factors are (1) the soil; (2) the seasonal and annual rainfall; (3) the seasonal evaporation; (4) the wind, with special reference to that which passes directly over the ground surface during the growth of the crop; and (5) the temperature, especially the killing frosts of spring and autumn that limit the growing season. The data on these factors, which follow, have been recorded at the Williston substation and at the station of the United States Weather Bureau in Williston.

SOIL.¹

The soil of the Williston substation is of an alluvial character, but it is variable in type. It is not typical of most of the best farming land outside of the valley. The creek-bottom flat consists of a heavy clay of the type described by the Bureau of Soils as Laurel clay. The larger portion of the substation consists of level or rolling land somewhat higher than the creek bottom. The somewhat variable soil on this portion is of the type known as Williston sandy loam. Water for irrigation is available on this part of the station farm.

That portion of the substation where the cereal experiments are conducted consists of a fairly level upland area, on which irrigation water is not available. The soil, which is fairly uniform in type, is classed as Laurel fine sandy loam.

NATIVE VEGETATION.

A biological survey was made of the Williston area in 1906.² The most important native vegetation found prevailing on the prairie included grama grass (*Bouteloua oligostachya*), buffalo grass (*Bulbuls dactyloides*), western wheat-grass (*Agropyron occidentale*), slender wheat-grass (*Agropyron tenerum*), and needle grass (*Stipa comata* and *Stipa viridula*). The grama grass grows abundantly over the prairie and makes a very nutritious pasture and excellent hay. The buffalo grass is just as nutritious, but is found more in spots and is never tall enough for hay. The western and slender wheat-grasses are found in the wild state and will replace the other native grasses when the sod is broken. They are grown extensively for the production of hay.

RAINFALL.

Table I shows the precipitation record for the Williston locality for a period of 36 years, from 1879 to 1914, inclusive. Previous to 1893 the weather records were kept at Fort Buford, N. Dak., 20

¹ For a full report on the soils of the Williston locality, see Rice, T. D., Willard, R. E., and Weaver, J. T., *Soil survey of the Williston area, North Dakota*. In U. S. Dept. Agr. Bur. Soils Field Oper. 1906, 8th Rpt., p. 999-1022, fig. 24, 1908.

² Bell, W. B. *Report of the biological survey of North Dakota*. In 4th Bien. Rpt. Agr. Col. Survey N. Dak., p. 28-51, 1910.

miles west of Williston. In December of that year the station of the Weather Bureau was moved to Williston. The Biophysical Laboratory of the Bureau of Plant Industry installed weather instruments at the Williston substation in 1909, and since that year the rainfall recorded there for the months during the growing season (April to July, inclusive) is used in the rainfall table. The growing season for the small grains extends from April to about August 1 to 10. The crops are so nearly mature on August 1, however, that precipitation after that date has little effect on yields. The table shows the rainfall, by months for the growing season and for the year, with monthly averages, maxima, and minima.

TABLE I.—*Monthly, annual, and seasonal precipitation, with the average, maximum, and minimum for each month, at Williston, N. Dak., 1879 to 1914, inclusive.*

[Data (in inches) from the records of the U. S. Weather Bureau and the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.	April to July, seasonal.
1879.....	0.58	0.59	0.03	2.75	5.56	3.35	3.63	0.18	Trace.	1.55	0.37	1.68	20.27	15.29
1880.....	.10	.51	.21	.74	4.02	5.46	4.17	2.36	1.04	.90	.66	3.08	23.25	14.39
1881.....	1.98	1.10	1.17	1.34	1.00	3.45	1.22	1.10	.58	.39	.39	.09	13.81	7.01
1882.....	.26	.29	.69	.94	1.61	1.87	2.25	.16	2.86	1.00	.29	.51	12.73	6.67
1883.....	1.98	.36	.91	.48	.59	.97	1.69	1.96	.22	1.41	.14	.11	10.82	3.73
1884.....	.11	.12	.10	1.30	.14	.99	1.87	1.06	.53	.44	.31	.40	7.37	4.30
1885.....	.64	.44	.03	1.71	1.02	6.05	3.02	1.50	.26	.19	.56	.14	15.56	11.80
1886.....	.41	.71	.31	2.25	1.14	.93	.56	.87	.05	1.57	.59	.55	10.24	4.88
1887.....	.51	.18	.12	1.09	1.59	3.25	2.00	3.91	1.07	1.43	.10	.18	15.43	7.93
1888.....	.47	.33	.44	.61	.96	6.75	2.12	1.61	.62	.62	.10	.07	14.70	10.44
1889.....	.13	.30	.20	.60	2.69	1.03	.63	.95	1.13	.01	.37	.42	8.46	4.95
1890.....	.22	.18	.58	.60	1.58	5.23	1.06	.22	2.05	2.45	.03	.04	14.24	8.47
1891.....	.19	.14	.27	1.84	1.49	7.08	2.99	.78	.66	1.96	1.44	.14	18.98	13.40
1892.....	.14	.38	.38	2.65	.48	2.41	4.49	.62	.11	.15	1.12	1.33	14.26	10.03
1893.....	2.04	.31	.12	.38	4.79	1.84	1.85	.31	.64	1.14	.56	1.92	15.90	8.86
1894.....	.88	.20	2.23	2.07	3.15	4.68	.02	.73	1.50	1.05	.85	.40	17.76	9.92
1895.....	.53	.47	.07	2.52	3.02	3.67	2.55	1.03	.32	.35	1.91	.63	17.07	11.76
1896.....	2.02	.71	1.80	2.86	5.79	3.45	1.22	.72	.89	.34	2.10	.14	22.04	13.32
1897.....	.56	1.10	2.10	1.17	.72	2.71	1.36	.45	.58	.43	.85	.16	12.19	5.96
1898.....	.01	.74	1.25	1.08	1.21	4.56	1.93	.23	.99	2.08	.30	.06	14.44	8.78
1899.....	.58	.10	.79	.60	2.39	3.72	1.91	.56	.01	1.06	.13	.76	12.61	8.62
1900.....	.03	.85	1.25	.57	1.46	.65	2.34	4.47	2.24	1.03	.71	.21	15.81	5.02
1901.....	.54	.34	.26	.46	.71	8.84	2.71	.74	1.77	.14	1.02	.83	18.36	12.72
1902.....	.09	1.52	1.36	.53	2.69	3.92	3.43	1.26	.33	.32	.72	.68	16.85	10.57
1903.....	.40	.27	.09	.79	3.94	2.06	2.43	5.02	1.39	.05	.18	1.07	17.69	9.22
1904.....	.58	.59	1.57	.78	1.27	2.58	.56	.57	.12	.23	.01	.58	9.44	5.19
1905.....	.10	.14	.18	.04	1.74	3.44	1.94	.74	1.93	.06	.31	.04	10.66	7.16
1906.....	.82	.03	.16	1.59	4.55	8.80	.50	2.39	1.18	.26	1.00	.73	22.01	15.44
1907.....	1.03	.13	.66	.53	1.11	2.03	1.82	2.06	.45	.08	.02	.26	10.18	5.49
1908.....	.31	.39	.79	1.96	1.80	2.64	.60	1.11	2.18	1.18	.16	.01	13.49	7.00
1909.....	.04	.10	.12	.64	2.84	3.72	1.72	.38	1.27	.17	.20	.46	11.93	8.92
1910.....	.27	.34	1.23	1.40	1.30	1.65	1.27	1.69	.14	.05	.66	.28	10.28	5.62
1911.....	.56	.34	.42	.32	3.00	1.37	1.40	2.56	2.49	.53	1.25	.59	14.83	6.09
1912.....	.44	.17	.35	2.13	4.59	1.59	3.60	3.47	1.21	1.12	.14	.18	18.99	11.91
1913.....	.52	.14	.94	.15	1.05	2.15	2.60	5.50	1.13	.94	.15	Trace.	15.27	5.95
1914.....	.55	.28	.50	.49	1.31	7.98	2.32	3.55	.64	.38	.24	.33	18.47	12.00
Average.....	.57	.41	.66	1.17	2.17	3.52	1.99	1.58	.96	.75	.55	.53	14.90	8.86
Maximum.....	2.04	1.52	2.23	2.86	5.79	8.84	4.49	5.50	2.86	2.45	2.10	3.08	23.25	15.44
Minimum.....	.01	.03	.03	.04	.14	.65	.02	.16	Trace.	.01	.01	Trace.	7.37	3.73

The average annual precipitation for the period of 36 years, as shown by Table I, is 14.90 inches. The maximum for any one year was 23.25 inches (in 1880) and the minimum was 7.37 inches (in 1884). During the same period the average precipitation for the

growing season (April to July, inclusive) was 8.86 inches. The maximum for any one growing season was 15.44 inches (in 1906) and the minimum was 3.73 inches (in 1883).

The rainfall is presented in graphic form in figure 1. The entire height of the vertical columns represents the precipitation in inches for the different years and the black lower portion shows the rainfall for the growing season (April to July, inclusive) for the same years. The lower horizontal line represents the average seasonal

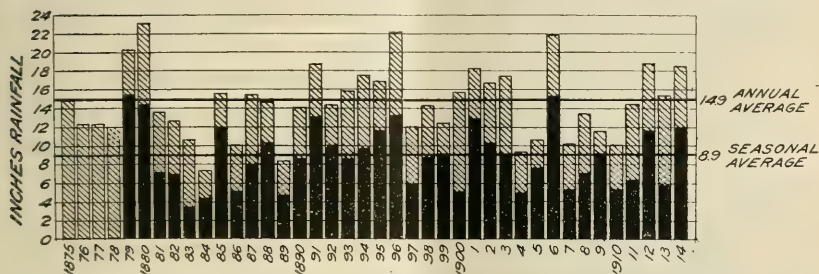


FIG. 1.—Diagram showing the precipitation at Williston, N. Dak.: Annual and average for the 40-year period from 1875 to 1914, inclusive (shaded columns); seasonal (April to July) for the 36-year period from 1879 to 1914, inclusive (solid black columns).

rainfall for the growing season and the upper horizontal line the average annual precipitation for the 36 years included in Table I.

EVAPORATION.

Table II shows the monthly precipitation and monthly evaporation during the growing season (April to July, inclusive) for the six years from 1909 to 1914, inclusive. The evaporation as well as the precipitation is an important controlling factor on the growth of crops in the entire Great Plains area. The evaporation is determined from a free water surface, the method being the one generally in use where the Biophysical Laboratory of the Bureau of Plant Industry has been cooperating.¹

TABLE II.—*Monthly precipitation and evaporation at the Williston substation for the growing season, 1909 to 1914, inclusive.*

[Data (in inches) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Apr.		May.		June.		July.		Total.	
	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.
1909.....	0.64	3.000	2.84	6.466	3.72	5.173	1.72	6.018	8.90	20.657
1910.....	1.40	5.346	1.30	5.764	1.65	8.171	1.27	8.994	5.62	28.269
1911.....	.32	5.790	3.00	6.087	1.37	7.145	1.40	8.717	6.09	27.739
1912.....	2.13	3.875	4.59	4.781	1.59	6.468	3.60	5.980	11.91	21.104
1913.....	.15	4.432	1.05	5.229	2.15	7.676	2.60	7.154	5.95	24.491
1914.....	.49	3.866	1.31	5.003	7.98	5.289	2.32	7.162	12.00	21.920
Average.....	.86	4.384	2.35	5.655	3.08	6.654	2.15	7.337	8.43	24.030

¹ Briggs, L. J., and Belz, J. O. Dry farming in relation to rainfall and evaporation. U. S. Dept. Agr., Bur. Plant Indus. Bul. 188, p. 16-20, 1910.

Table II shows that for no month during the six years does the precipitation exceed the evaporation from a free water surface. The average monthly precipitation for the six years is shown to be greatest during June, 3.08 inches. The average evaporation during June for the same period of years is 6.65 inches, or more than twice the rainfall. The average rainfall for the four months (April to July)

during the six years is 8.43 inches, and the evaporation for the same period of time is nearly three times as great, or 24.03 inches.

Figure 2 presents graphs showing the average monthly precipitation and evaporation in inches for the four months from April to July for the six years from 1909 to 1914, inclusive.

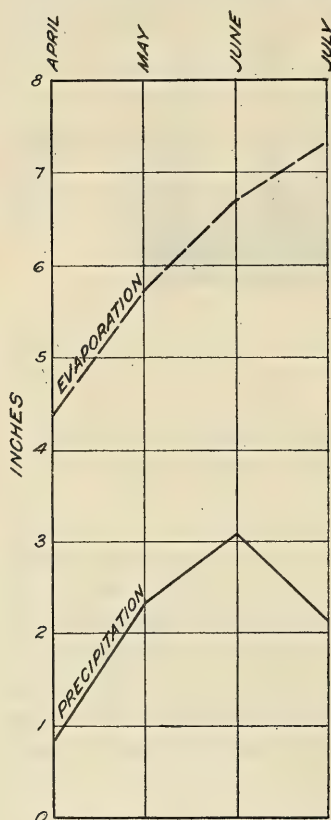


FIG. 2.—Graphs showing the average monthly precipitation and evaporation during the growing season (April to July, inclusive) at Williston, N. Dak., 1909 to 1914, inclusive.

WIND.

The average monthly wind velocity for the six years from 1909 to 1914, inclusive, is shown in Table III.

TABLE III.—Average wind velocity at the Williston substation, by months, for the growing season, 1909 to 1914, inclusive.

[Data (in miles per hour) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Apr.	May.	June.	July.	Average.
1909.....			7.0	5.8	
1910.....	8.7	8.0	7.0	5.7	7.4
1911.....	8.8	8.6	6.9	6.1	7.6
1912.....	7.2	7.9	6.1	3.8	6.3
1913.....	8.1	6.5	6.3	4.2	6.0
1914.....	6.6	7.1	4.9	3.5	5.5
Average.....	7.9	7.6	6.4	4.9	6.6

The anemometer used at Williston stands about 2 feet from the surface of the ground and near the evaporation tank. Table III shows that the average wind velocity from April to July is 6 miles per hour. It also may be seen that generally there is a decrease in the velocity of the wind each month from April to July. In seasons of normal rainfall protracted hot winds are not common. In seasons of unusually low precipitation hot winds may prevail, as was the case in 1910, when successive hot winds occurred for a period of about four days in June, practically ruining the small-grain crops.

TEMPERATURE.

The daily variations in temperature at Williston are recorded automatically by a thermograph. These records are checked by the use of maximum and minimum thermometers. The mean, maximum, and minimum temperatures, by months, during the growing season for the years 1909 to 1914, inclusive, are shown in Table IV.

Table IV shows that the highest monthly mean temperature is for July. This is the only month that a minimum lower than 32° F. has not occurred in some one of the six years.

The frost-free period is shown in graphic form in figure 3, covering a period of 33 years (1882 to 1914). It shows that the average date of the last killing frost in the spring is May 18 and that the average date of the first frost in the autumn is September 14. The shortest period between frosts, as shown by the graph, was 80

days (in 1883) and the longest period was 155 days (in 1905). The average frost-free period for the 33 years is 119 days.

Previous to 1893, the temperature records were kept at Fort Buford and since that date at Williston.

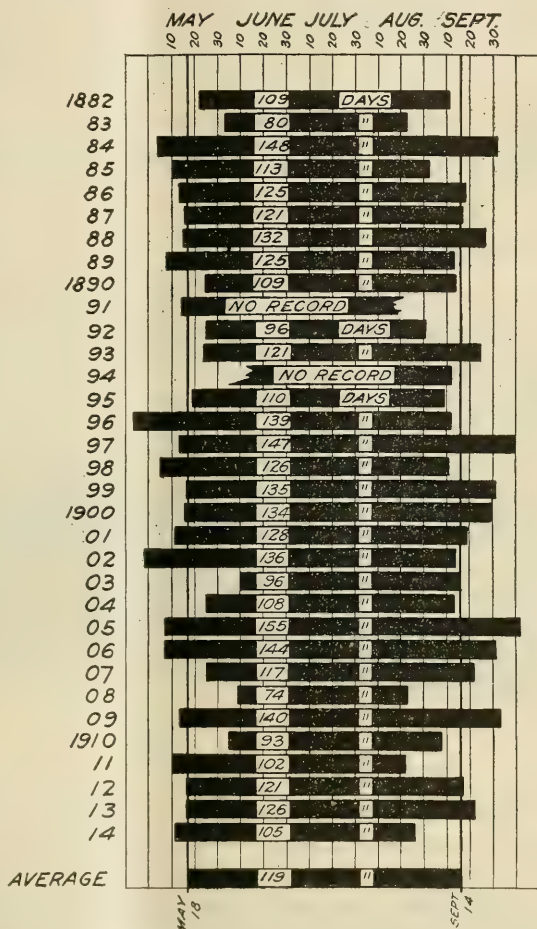


FIG. 3.—Diagram showing the length of the frost-free period and the average dates of the last killing frost in spring and the first in autumn for the 33-year period from 1882 to 1914, inclusive, at the Williston station.

TABLE IV.—*Summary of mean, maximum, and minimum temperatures at the Williston substation, by months, for the growing season, 1909 to 1914, inclusive.*

[Data (in °F.) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Apr.			May.			June.			July.			Seasonal mean.
	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	
1909.....	35	62	9	51	86	20	61	91	40	67	94	47	54
1910.....	50	92	12	51	81	25	67	105	32	68	104	43	59
1911.....	42	89	12	56	90	15	68	100	43	65	99	38	58
1912.....	45	68	19	54	85	31	64	99	32	65	90	38	57
1913.....	47	89	19	52	95	22	67	95	41	67	93	40	58
1914.....	48	79	10	54	86	20	62	92	39	73	100	44	59
Average.....	45	-----	-----	53	-----	-----	65	-----	-----	68	-----	-----	58

EXPERIMENTAL METHODS.

In all the varietal tests at Williston the primary objects have been to determine the relative yielding powers of the varieties and to increase the yield and quality through the selection of standard varieties or the importation of new ones.

The work has been conducted along the two lines usual on experiment farms: (1) Testing in field plats under conditions that conform as closely as possible to farm practices, and (2) testing in nursery rows, where a very much larger number of varieties or races can be grown more economically than is possible in large plats.

The work of testing and improving cereals has included both spring and winter varieties, but the greater part of the work has been with spring cereals

PLAT EXPERIMENTS.

DIMENSIONS OF PLATS.

The field tests were conducted on plats approximately one-twentieth of an acre in area. The plats have varied slightly each year in size and shape, but all plats were uniform in size for each year. The approximate dimensions have been 8 feet wide (the width of the drill used) and $272\frac{1}{4}$ feet long, but in some years they were longer and narrower and in other years they were shorter, making an area slightly more or less than one-twentieth of an acre. The alleys between the plats have been 18 inches wide. A general view of the plats is shown in figure 4

TREATMENT OF PLATS.

In 1908, the first year during which the Williston substation was operated, all of the field plats were located on old ground that had borne oats the previous year. The following two years, 1909 and 1910, the varietal plats were located on new ground and were therefore in a different location each year. In each case, the virgin soil

was broken in June of the previous year. After breaking to a depth of 6 inches, the ground was disked and harrowed and kept free from weeds during the remainder of the season.

In 1911 the varieties were grown on ground that produced a corn crop the previous year. In 1912 the plats were on breaking, as in 1909 and in 1910. In 1913 and 1914 they were on summer-fallowed ground.

In the spring of each year the ground was worked sufficiently to put it in good condition for seeding. It was disked when necessary and was harrowed two or more times. In the case of fallow, harrowing or disking was done frequently enough to keep down all weed growth throughout the season. The plats were given no further cul-



FIG. 4.—View at the Williston substation in 1914, showing the long, narrow plats of cereal varieties in the background.

tivation after seeding, but the alleys between were kept free from weeds.

TREATMENT OF CROPS.

The seeding has been done with a double-disk 8-foot drill with a 6-inch spacing between the disks. The wheat and oats were seeded usually during the last part of April, and the barley and flax somewhat later. With the exception of flax, which should not be sown very deep, the small grains were seeded from 2 to 3 inches in depth. The seeding in each case was at the rate which was considered best for the locality.

After the crops headed they were freed from mixtures by roguing. The cutting was done with a binder and the bundles placed in shocks, where they remained until thrashed. Thrashing has been done with a small separator with a 12-inch cylinder. Great care was used to avoid the mixing of varieties in harvesting and thrashing.

PLAT RECORDS.

The first note taken after emergence was of the comparative stand. Since seeding was uniform for each cereal or comparable group of varieties, uniform stands of plants could be expected when the germination was perfect. However, these conditions were noted after the plants emerged and a comparison of stands of the different plats was taken.

Other important notes were recorded throughout the season, such as dates of heading, ripening, and cutting. If smut, rust, or other diseases were present, such data were recorded.

As each variety was thrashed the weight of the grain from the plat was recorded. This weight was then divided by the standard bushel weight and the yield in bushels per acre determined.

Previous to 1912 the varieties of cereals were grown in single plats without checks. In 1912 and 1913 check plats were used. In 1914 all varieties of cereals were sown in duplicate fiftieth-acre plats.

SOURCE OF THE SEED.

The cereals grown in the plat tests have come from many different sources. The first year nearly all of the seed was obtained from the North Dakota Agricultural Experiment Station or from the Edgeley substation. Since that time varieties have been obtained from various sources in North Dakota and in other States, and also from foreign countries having a climate similar to that of the northern Great Plains area. Promising varieties from the cereal nursery also have been increased and grown in the field tests.

NURSERY EXPERIMENTS.

Many varieties and races of cereals have been tested in nursery rows. This method has permitted work with a much larger number of varieties here than in the larger plats. The ground used each year was usually cultivated land that had borne potatoes or corn the previous year. In this way the land was kept free from volunteer grain. Special care was given to the selection of uniform soil, to uniformity in the rate of seeding, and to the spacing and length of rows. More detailed notes were made throughout the season than were taken of the varietal plats under field conditions.

The nursery consisted of centgeners, head rows, and rod rows. In 1908 it was planted entirely in centgeners, from each of which the best plant was selected each year for planting the following year. The number of centgeners decreased each year until 1912, after which this method was discarded. In 1909 the use of head rows and rod rows was begun, and in 1913 these entirely replaced the centgeners.

Table V shows the number of centgeners, head rows, and rod rows planted each year since 1908. The number of rows of winter wheat grown each year since 1911 is shown separately. The winter-wheat rows have been 1 rod long or shorter.

TABLE V.—*Number of plantings of spring and winter cereals in centgeners and in rows at the Williston substation, 1908 to 1914, inclusive.*

Year.	Spring cereals.			Winter wheat rows.	Year.	Spring cereals.			Winter wheat rows.
	Cent-geners.	Head rows.	Rod rows.			Cent-geners.	Head rows.	Rod rows.	
1908.....	156				1912.....	53	343	507	125
1909.....	107	87	359		1913.....		500	180	100
1910.....	111	426	339		1914.....		546	175	75
1911.....	55	280	200	90					

CENTGENERS.

In 1908 there were 156 centgenger plats. The number decreased each year until 1913, when centgeners were discontinued. The centgenger plats were planted in squares with one seed in a place, the seeds being 4 inches apart each way. Each centgenger was sown with seed from a single plant. A complete centgenger contained 100 seeds, if a plant produced that number. Around the outside of the plat two rows of some other variety were sown for protection.

The best plant in each centgenger plat each year was selected for planting the following year. All inferior plants were discarded. The plant selected for continuing the centgenger was the one which approached most nearly the standard sought.

HEAD ROWS.

The head rows are 5 feet in length and 12 inches apart. The seeds are spaced 3 inches apart in the row, thus requiring 20 seeds for each row.

The material tested in head rows came from various sources. Much of it was in the form of individual heads chosen from the varietal plats of wheat, oats, and barley, or from farm fields. Each such head was planted in a head row.

When the work was begun, it was thought that improvement would result from continuous selection within a pure line. The best plant was selected each year from the head row, just as in the centgenger, and its seed sown the following year. This plan was abandoned in 1912. Thereafter a race was kept in the head row but a single year. If inferior, it was discarded. If promising, a rod row was sown the following year with bulk seed from the head row. Notes were taken throughout the season on heading, ripening, yields, and such other factors as were considered essential to proper comparisons.

ROD ROWS.

Previous to 1912 the rod rows were planted by opening a furrow, distributing the seed as uniformly as possible by hand, and then covering the rows. In 1912 each row was planted with 210 seeds 1 inch apart in the row. These rows were $17\frac{1}{2}$ feet long, but the plants from 6 inches at each end of the row were discarded to reduce as much as possible the border effect. Only $16\frac{1}{2}$ feet were harvested.

The writer has devised a planter for placing the seeds at uniform intervals in the row. This device, which was first used in 1912, is fairly satisfactory as compared with the method formerly used in planting. The planting device consists of a V-shaped trough $17\frac{1}{2}$ feet long made in two sections of $8\frac{3}{4}$ feet each. It is made of boards 3 inches wide and 1 inch thick. Transverse grooves were made 1



FIG. 5.—View of the cereal nursery at the Williston substation in 1912.

inch apart on the inside of one wing of the trough. A seed is placed in each of the notches and remains in its position until the planter is tipped into the opened furrow. Each of the 210 seeds then rolls down the groove and drops into position in the row.

The trough may be raised on supports 3 or 4 feet from the ground while the seeds are being placed in the grooves. The seeds are placed in the grooves quite rapidly by shaking them from the open end of an envelope held in the hand. Those that fall out of place are quickly moved with a pair of tweezers.

The row is opened with a small hand plow. The trough with seeds in place is then lifted from its supports, the seeds turned into the opened furrow, and then covered. Very uniform stands have been obtained in all rows during the years the planter has been used.

The rod rows have contained sowings of the varieties used in field tests, newly imported cereals obtained through the Office of Cereal

Investigations, selected pure races from the head-row tests, and any other samples desired for comparison with standard varieties. When promising varieties were discovered, they were increased and placed in the field-plat tests. Taganrog durum wheat (C. I. No. 1570) and a pure line of Manchuria barley (C. I. No. 882) are good examples.

Figure 5 shows a portion of the cereal nursery at Williston in 1912.

EXPERIMENTS WITH WHEAT.

In the Williston district, spring wheat is grown almost exclusively. Winter wheat has been tried in northwestern North Dakota and adjoining portions of Montana, but with poor results. In most years the winterkilling has been very heavy, and sometimes all the plants have been killed. Occasionally the crop has been quite successful, with little or no winterkilling, giving better results than spring wheat for those particular years. The tests at the Williston substation thus far have shown that winter wheat has not been a dependable crop.

SPRING WHEAT.

The spring wheats of the North-Central States belong to one or the other of two subspecies of wheat, durum and common. The common subspecies include the three groups, fife, bluestem, and preston, as well as a few miscellaneous varieties.

The spring-wheat varieties have been grown each year on newly broken land, on corn ground, or on fallow. When there were indications of the presence of smut the seed has been treated before sowing. Until 1911 the rate of seeding had been 5 pecks of common wheat and 6 pecks of durum wheat per acre. Since that time they have been seeded at the rate of 4 pecks for common and 5 pecks for durum wheat. In the rate-of-seeding tests this latter rate has been found to give as good results as heavier seeding.

The annual yields produced by all the varieties of spring wheat grown at Williston during the seven years (1908 to 1914) are given in Table VI. The varieties are arranged in five groups, according to their relationships. The groups appear in the table in the order of their importance in this locality. Of the 35 varieties grown during the seven years, only 20 were grown in 1914. Seven varieties have been grown for all of the seven years. Table VI also shows the average yield of each variety for the years during which it has been grown.

The average annual yields of the different groups are shown in Table VI for each of the years from 1908 to 1914. The durum group made the highest yield in five out of the seven years. In 1910 the durum group yielded lower than any other, and in 1911 it yielded lower than any other except the bluestem and the miscellaneous groups.

TABLE VI.—*Annual and average yields, by groups, of 35 varieties of wheat grown at the Williston substation, 1908 to 1914, inclusive.*

Group, Cereal Investigations number, and variety.	Yield per acre (bushels).							Average.
	1908	1909	1910	1911 ^a	1912	1913	1914	
Durum group:								
1494, Arnautka (N. Dak. No. 778).....	10.6	32.0						21.3
3693, Arnautka.....	15.6	37.4	6.1	8.2	49.7	34.7	47.2	28.4
4064, Arnautka 6 P 4.....							50.0	50.0
3657, Australian.....							49.6	49.6
1443, Gharnovka (N. Dak. No. 917).....	11.0	37.1						24.1
1447, Gharnovka.....	15.8	35.5	9.3	10.5	46.0	34.8		25.3
1447, Gharnovka (selection).....						31.0		31.0
1440, Kubanka.....	12.6	39.1	11.0	8.9	51.0	33.0	53.8	29.9
4063, Kubanka No. 8.....							45.0	45.0
2086, Pelissier (selection).....						25.3		25.3
1350, Pererodka.....	12.8	34.8	9.5	7.3	48.3	33.7		24.4
1570, Taganrog (selection).....						35.0	54.6	44.8
1445, Velvet Don.....	15.6	36.8	3.7	8.9	43.3	25.0		22.2
Average.....	13.4	36.1	7.9	8.8	47.7	31.6	50.0	
Fife group:								
1517, Ghirka Spring.....		33.2	20.2	12.1	51.7	22.2	40.4	30.0
2873, Glyndon (Minn. No. 163).....	9.8	31.2	13.9	8.0	44.7	28.2	49.2	26.4
3641, Marquis.....						29.0	52.5	40.8
Power (N. Dak. No. 312).....	11.9	(^b)	12.4					12.2
Power (N. Dak. No. 317).....	14.0	(^b)	11.0					12.5
3697, Power (N. Dak. No. 313).....	13.1	34.0	17.1	11.1	44.7	28.7	51.3	28.6
3694, Red Fife (N. Dak. No. 646).....	11.3	34.2	14.9	10.2	46.0	28.7	47.9	27.6
Average.....	12.0	33.2	14.9	10.4	46.8	27.4	48.3	
Preston group:								
3328, Preston (Minn. No. 188).....							47.2	47.2
3692, Preston (N. Dak. No. 2393).....			9.1	10.2	45.5	26.7		22.9
3698, Preston.....		26.2	13.4	12.7	44.7	25.0	46.3	28.1
Average.....		26.2	11.3	11.5	45.1	25.9	46.8	
Bluestem group:								
3314, Crossbred (N. Dak. No. 318).....	11.2	31.0	12.4	^d 4.9	43.0			20.5
3083, Dakota (N. Dak. No. 316).....	16.7	35.1	11.1	10.9	42.3	30.7	47.5	27.8
3021, Haynes (Minn. No. 51).....	14.2	35.9	11.0	9.2	42.3	29.2	46.3	26.9
2874, Haynes (Minn. No. 169).....	10.5	34.3	8.8		44.3	30.0	42.5	28.4
Haynes (selection).....				9.0				9.0
3082, Marvel (N. Dak. No. 722).....	13.0	35.9	11.0	^d 3.8	41.0			20.9
Average.....	13.1	34.2	10.9	7.6	42.6	30.0	45.5	
Miscellaneous group:								
2398, Galgalos.....						27.7		27.7
3690, Humpback (N. Dak. No. 2365).....			12.4	8.9	41.7	30.0		23.3
3315, Huron.....							52.2	52.2
2492, Manchuria.....						19.7	46.7	33.2
3008, Wolkoren.....							42.7	42.7
3700, World Beater.....				4.9	40.7	27.0	38.8	27.9
Average.....			12.4	6.9	41.2	26.1	45.1	
Summary of averages:								
Durum group.....	13.4	36.1	7.9	8.8	47.7	31.6	50.0	
Fife group.....	12.0	33.2	14.9	10.4	46.8	27.4	48.3	
Preston group.....		26.2	11.3	11.5	45.1	25.9	46.8	
Bluestem group.....	13.1	34.2	10.9	7.6	42.6	30.0	45.5	
Miscellaneous group.....			12.4	6.9	41.2	26.1	45.1	

^a All varieties in 1911 were slightly damaged in the shock by hail.^b Yields lost.^c Average of 3 plats.^d Not comparable with other yields for 1911.

Of the common wheats, the bluestem group was highest in yield in 1908, 1909, and 1913, the fife group was highest in 1910 and 1912, and the preston group in 1911 and 1914.

A summary of the yields of twelve standard varieties of wheat at Williston is given in Table VII. Seven of these varieties have been tested for the entire period of seven years, two for six years, and three for only two years. The average yields for each of these three periods are shown. The varieties in Table VII are arranged according to these groups.

TABLE VII.—*Annual and average yields of 12 varieties of spring wheat grown at the Williston substation for three different series of years between 1908 and 1914.*

Group, Cereal Investigations number, and variety.	Yield per acre (bushels).									
	1908	1909	1910	1911	1912	1913	1914	Average.		
								1908 to 1914.	1909 to 1914.	1913 and 1914.
Durum group:										
1440, Kubanka.....	12.6	39.1	11.0	8.9	51.0	33.0	53.8	29.9	32.8	43.4
3693, Arnautka.....	15.6	37.4	6.1	8.2	49.7	34.7	47.2	28.4	30.6	41.0
1570, Taganrog.....						35.0	54.6			44.8
Fife group:										
3697, Power.....	13.1	34.0	17.1	11.1	44.7	28.7	51.3	28.6	31.2	40.0
3694, Red Fife.....	11.3	34.2	14.9	10.2	46.0	28.7	47.9	27.6	30.3	38.3
2873, Glyndon (Minn. No. 163) ¹	9.8	31.2	13.9	8.0	44.7	28.2	49.2	26.4	29.2	38.7
1517, Ghirka.....		33.2	20.2	12.1	51.7	22.2	40.4		30.0	31.3
3641, Marquis.....						29.0	52.5			40.8
Preston group:										
3698, Preston.....		26.2	13.4	12.7	44.7	25.0	46.3		28.1	35.7
Bluestem group:										
3083, Dakota (N. Dak. No. 316).....	16.7	35.1	11.1	10.9	42.3	30.7	47.5	27.8	29.6	39.1
3021, Haynes (Minn. No. 51).....	14.2	35.9	11.0	9.2	42.3	29.2	46.3	26.9	29.0	37.8
2874, Haynes (Minn. No. 169).....						30.0	42.5			36.3

¹ Previous to 1911 the Glyndon variety was grown from seed originally obtained from the Edgeley substation in North Dakota; in 1911 and succeeding years it was grown from seed originally from the Minnesota Agricultural Experiment Station.

For the period of seven years the Kubanka durum wheat (C. I. No. 1440) made the highest yield, 29.9 bushels per acre. The Power fife wheat was second in yield, with an average of 28.6 bushels. These varieties also led for the 6-year period (1909 to 1914), during which the Ghirka (C. I. No. 1517) and the Preston (C. I. No. 3698) were included. Figure 6 shows graphically the annual and average yields of the leading varieties within the four different groups for the six years from 1909 to 1914, inclusive.

In 1913 the Taganrog (C. I. No. 1570), Marquis (C. I. No. 3641), and Haynes (C. I. No. 2874) were added to the test. The averages for 1913 and 1914 show that in the durum group the Taganrog variety yielded more than the Kubanka, and that in the fife group the Marquis variety was better than the Power.

The average dates of heading and of ripening, number of days from planting to heading and to maturity, height, yield per acre, and weight per bushel of grain for the varieties grown during the 6-year period (1909 to 1914) are shown in Table VIII. Figure 7 shows heads of eight representative varieties of the four groups of spring wheat.

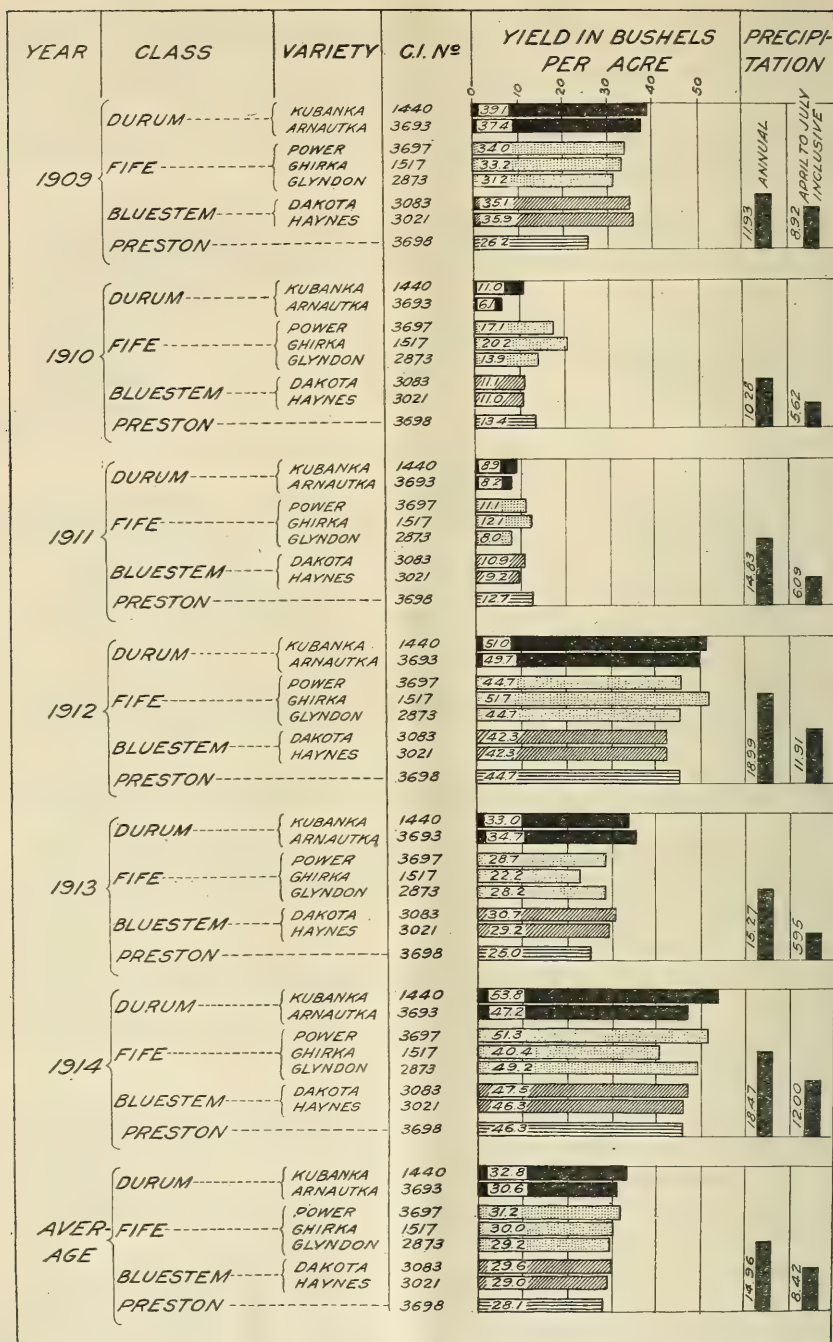


FIG. 6.—Diagram showing the annual and average yields of leading varieties in four different groups of spring wheat at the Williston substation, with data on the annual and seasonal precipitation for the six years from 1909 to 1914, inclusive.

TABLE VIII.—Average growth data, yields per acre, and weight of grain per bushel for nine varieties of wheat at the Williston substation, 1909 to 1914, inclusive.

Group, Cereal investigations number, and variety.	Average date.		To maturity from—		Height.	Yield per acre.	Weight per bushel.
	Headed.	Ripe.	Planting.	Heading.			
Durum group:			<i>Days.</i>	<i>Days.</i>	<i>Inches.</i>	<i>Bushels.</i>	<i>Pounds.</i>
1440, Kubanka.....	July 8	Aug. 3	105	26	39	32.8	62.0
3693, Arnautka.....	do.	do.	105	26	39	30.6	61.5
Fife group:							
3697, Power.....	July 11	Aug. 4	107	24	35	31.2	60.8
3694, Red Fife.....	do.	do.	106	24	36	30.3	58.6
2873, Glyndon (Minn. No. 163).....	July 13	do.	107	22	35	29.2	58.2
1517, Ghirka.....	July 7	July 30	102	23	35	30.0	60.7
Preston group:							
3698, Preston.....	July 11	Aug. 2	103	22	35	28.1	60.7
Bluestem group:							
3083, Dakota (N. Dak. No. 316).....	July 13	Aug. 6	108	24	37	29.6	57.4
3021, Haynes (Minn. No. 51).....	do.	do.	107	24	37	29.0	57.1

Table VIII shows that the date of heading is earlier for the durum than for the other groups, but they require a longer period from heading to maturity and ripen at about the same time. They also

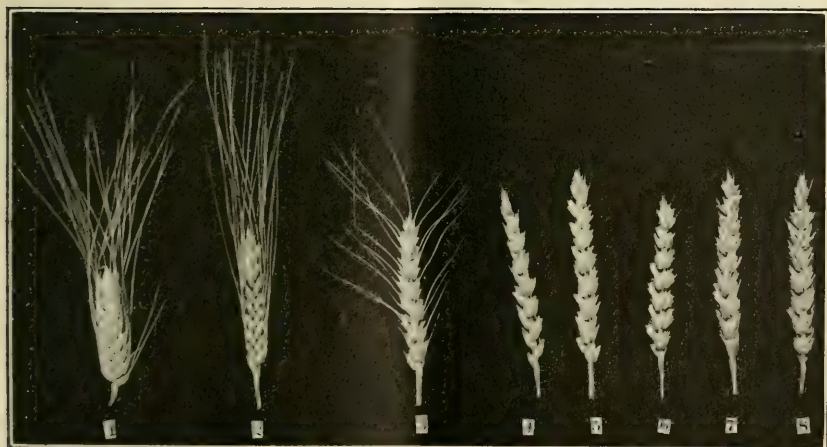


FIG. 7.—Heads of representative varieties of the four groups of spring wheat grown at the Williston substation: Durum group—Kubanka (1) and Arnautka (2); preston group—Preston (3); fife group—Ghirka (4), Rysting (5), and Marquis (6); bluestem group—Crossbred (7) and Haynes (8).

grow tallest and have the heaviest bushel weight. The Ghirka and the Preston are the earliest maturing varieties. The bluestem varieties head and ripen later than the varieties of the other groups. They also have the lowest bushel weight.

DURUM GROUP.¹

Durum wheat was introduced into the United States from Russia in 1899 by Mr. Mark Alfred Carleton, Cerealist of the United States Department of Agriculture. The durum wheats have rather long, tough straw and large, heavy, bearded heads. The kernels also are large and the bushel weight is high. The grains are held very tightly within the glumes, thus enabling them to stand without shattering for some time after becoming ripe. Because of the weight of the heads, they have a tendency to droop over as the grain ripens, which makes the durums more difficult to cut with a binder than the fife and bluestem wheats.

In 1910 and 1911 the yields of the durum wheats were lower than those of the other groups. These two years were characterized by low rainfall and high evaporation during the growing season. In 1911 no protracted hot winds occurred, but in 1910 there were several days of continuous hot winds about the time wheat was heading. There was a normal growth of straw and heads each year, but a large percentage of the heads contained no kernels. This condition seemed to be peculiar only to the durum group.

Kubanka.—The Kubanka variety of durum wheat was introduced from Russia by the United States Department of Agriculture in 1899. It has a stout, rather broad head with yellowish, glabrous glumes and long yellow beards. Of the several durum varieties that have been tested at Williston, the Kubanka has given the best results, with the Arnautka second. Table VII shows that the Kubanka has the highest average yield of any variety for the 7-year period (1908 to 1914) or for the 6-year period (1909 to 1914). For the two years 1913 and 1914 it has given better yields than any other except the Taganrog (C. I. No. 1570).

Taganrog.—The Taganrog variety (C. I. No. 1570) closely resembles the Arnautka in having a slightly longer head than the Kubanka. In other respects the three varieties are very similar in appearance. The Taganrog appeared to be promising in the row tests in the cereal nursery, so it was increased and finally added to the field tests in 1913. For each of the years 1913 and 1914 it produced the highest yield of any of the wheats tested.

FIFE GROUP.

The varieties of the fife group are beardless and the glumes glabrous. They head and ripen a little earlier than the bluestems, as is shown in Table VIII. This is especially true of the Ghirka. Their height is somewhat less and the bushel weight considerably more than the average bluestems.

¹ For a more complete discussion and history of the wheat groups and their varieties see the following: Clark, J. A. Cereal experiments at Dickinson, N. Dak. U. S. Dept. Agr. Bul. 33, 44 p., 7 fig., 1 pl., 1914. Salmon, Cecil, and Clark, J. A. Durum wheat. U. S. Dept. Agr. Farmers' Bul. 534, 16 p., 4 fig., 1913.

The fife wheats have proved superior in most points to the bluestem group for the territory surrounding Williston. One of the principal points in their favor is that they do not shatter so badly when fully ripe. The tests made at Williston show that the quality of the fife grain is ordinarily better than that of the bluestem group.

Power.—The Power variety is a selection from the original Red Fife. It is said to have originated about 1885 with Mr. James Holes, of Fargo, N. Dak., from a single plant. It was increased and distributed in large quantities by Mr. J. B. Power, of Power, N. Dak.; hence the name. Seed from Mr. Power was given the number 66 by the experiment stations of both North Dakota and Minnesota. Later selections from Minnesota No. 66 were given the Minnesota numbers 149 and 276.

The average yield of Power fife (C. I. No. 3697) for the six years (1909 to 1914) has been 31.2 bushels per acre, as shown in Table VII. This is the highest yield made by any variety of common wheat tested at Williston for the same period. Power fife also has had the highest bushel weight of any variety tested except the durums, as shown in Table VIII.

Ghirka Spring.—The Ghirka wheat (C. I. No. 1517) came from Russia. It seems to possess better drought-resisting qualities than any of the other fifes or any of the bluestems tried at Williston. This quality was very noticeable during the two dry years, 1910 and 1911. In 1910 the yield of Ghirka exceeded that of any other wheat tested that year, and in 1911 it stood second in yield.

In 1910 and 1911 the heads of Ghirka filled completely to the tips, while the other fifes and bluestems did not. Ghirka has a longer, more tapering head than the other varieties of the fife group. The kernel of the Ghirka is larger than that of the other fifes or of the bluestems, but it is not as hard, and the milling quality is somewhat inferior.

Marquis.—The Marquis variety (C. I. No. 3641) was derived from a cross made in Canada between a hard red Calcutta wheat and Red Fife. This wheat is of comparatively recent origin and distribution. While grown for several years on the Dominion experiment farms in Manitoba, Saskatchewan, and Alberta, it has been in the tests at Williston but two years. During this time it has given results about equal to those from Power fife.

The growth of straw is shorter than that of the other fifes; the head also is shorter, and the grain is held more firmly within the glumes. The kernels are short, very plump, and the weight per bushel is good.

PRESTON GROUP.

The wheats placed together in the somewhat variable preston group are all bearded, with glabrous glumes and hard red kernels much like those of the fife group. In some of the varieties the milling

and baking qualities are similar, and in others they are somewhat inferior to the fifes. Some of the varieties have been known commercially as "velvet chaff." This name is unfortunate, since none of them have pubescent glumes. The preston wheats possess somewhat better drought-resistant qualities than those of either the ordinary fife or bluestem groups.

Preston.—The Preston variety (C. I. No. 3698) originated as a hybrid at Ottawa, Canada, about 1893, from a cross of Ladoga and Red Fife. It was selected there for earliness and stiff straw. It is the leading variety of this group. Its average yield for the six years (1909 to 1914) has not been as high as those of the other wheats shown in Table VII. It made a better yield than the bluestems, however, in the dry year 1910. In 1911, a second dry year, its yield was higher than that of any other wheat shown in Table VII.

BLUESTEM GROUP.

The bluestem group is composed of varieties with beardless heads and pubescent glumes. The bluestems head and ripen a little later than the fifes. At Williston they have yielded less than the fifes and their weight per bushel has been lower. Table VIII shows that the average weight per bushel falls below 58 pounds.

Bluestem wheat has been considered one of the best hard spring wheats to grow in the North-Central States. It possesses qualities that give it a high place as a bread wheat. The trials at Williston have shown that for that district it is inferior to the fife and durum groups in yield and in quality of grain. The weight per bushel has not averaged high enough to insure its being graded as No. 1 northern.

RATE-OF-SEEDING TEST WITH SPRING WHEAT.

An experiment to determine the best rate of seeding for spring wheat was begun in 1911. Dakota Bluestem (C. I. No. 3083) was the variety used. Six rates, varying from 3 to 8 pecks per acre, were tried in 1911. The 8-peck rate was discontinued at the end of that year and the 7-peck rate at the end of 1913. The results obtained are shown in Table IX.

TABLE IX.—*Annual and average yields in a rate-of-seeding test of Dakota Bluestem spring wheat at Williston, N. Dak., 1911 to 1914, inclusive.*

Rate of seeding.	Yield per acre (bushels).					Rate of seeding.	Yield per acre (bushels).				
	1911	1912	1913	1914	Average.		1911	1912	1913	1914	Average.
3 pecks..	1.9	43.7	15.7	41.1	25.6	6 pecks..	2.0	48.0	33.0	48.8	33.0
4 pecks..	2.2	49.0	31.5	47.5	32.6	7 pecks..	2.5	47.6	36.6	.....	.....
5 pecks..	1.7	49.5	30.3	50.4	33.0	8 pecks..	2.0	.....	.....	.....	.....

It will be seen that in none of the years was there any significant difference between the results from the seedings at 4, 5, and 6 pecks. The results from the 3-peck seeding are sufficiently lower to show that 3 pecks is not enough. Since the 4-peck rate gives as good results as the sowing of 5 or 6 pecks and requires less seed per acre, it should be considered the proper rate. The general practice of the farmers in the vicinity of Williston is to sow 4 pecks to the acre.

In each of the years the plat on which the 3-peck rate was seeded was more weedy throughout the season than the plats where the higher rates were used. Owing to the thinner stand of wheat plants in the 3-peck rate, the time from planting to maturity was several days longer each year. The bushel weight of the grain also was less. The average weights per bushel of grain were 56, 55½, 55, and 53½ pounds from the sowings at 6, 5, 4, and 3 pecks, respectively.

NURSERY TESTS OF SPRING WHEAT.

Table X presents certain nursery data for 84 races in the different groups of wheat. These were grown in the 17½-foot rows, planted each year with the planter that placed 210 seeds 1 inch apart in the row. These data are averages for the two years, 1912 and 1913. The same races were used in each of the two years.

The season of 1912 was a very good one for crop production. The rainfall was above normal for the growing period, April to July, inclusive. The season of 1913 was the reverse of 1912. It was exceedingly dry until the latter part of June, and the rainfall from April to July, inclusive, was considerably below normal.

TABLE X.—Average of miscellaneous data for 84 different races of wheat grown in rod rows at the Williston substation during 1912 and 1913.

Group and description.	Number of races.	Days to maturity.	Height.	Length of heads.	Stools per plant.	Heads per plant.	Weight of 1,000 kernels.	Yield per row.	
								Straw.	Grain.
Durum group:			<i>Inches.</i>	<i>Inches.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Smooth glumes.....	30	106	32.7	2.49	4.29	3.40	41.8	477	311.0
Hairy glumes.....	9	105	30.1	2.34	4.40	3.71	49.3	466	274.1
Common beardless group:									
Smooth glumes.....	18	104	36.1	3.55	5.29	4.45	30.7	519	312.1
Hairy glumes.....	12	104	37.9	3.37	5.60	4.42	26.5	553	306.0
Common bearded group:									
Smooth glumes.....	15	103	29.1	3.07	5.75	4.77	29.8	459	269.3

In the durum races, as shown by Table X, there were 30 with glabrous and 9 with pubescent glumes. Those with smooth glumes, which include the races of Kubanka and Arnautka, produced the best average yield of grain, 311 grams, compared with 274.1 grams per row from the pubescent-glumed races. The straw also was longer and heavier and the heads longer. The number of tillers, the length of heads, and the kernel weight were lower in the smooth-glumed than in the hairy-glumed races.

In the beardless common wheats there were 18 smooth-glumed and 12 hairy-glumed races. As in the durums, the smooth-glumed races (mostly fifes) produced more grain, longer heads, and fewer tillers per plant than the pubescent-glumed ones (mostly bluestems). The smooth-glumed races also had shorter and lighter straw, more heads per plant, and greater kernel weight than the hairy-glumed races.

In the field plats the fife (glabrous glumes) and the bluestem (pubescent glumes) groups gave similar results in a 6-year average. The fifes had shorter straw and heavier yields of grain, with heavier bushel weight, than wheats of the bluestem group.

WINTER WHEAT.

Winter wheat has been tried at Williston for six years, but the results so far obtained are not favorable. Winter wheat can not be grown here successfully, at least not until some hardier varieties are secured. In 1909, 1910, and 1912 the winter-wheat varieties were on ground that either was newly broken or had been fallowed. The other years they were in corn stubble, the cornstalks having been left standing during the winter.

In the first case the varieties had no protection during the winter except the covering of snow that the plants themselves held, and winterkilling was severe in all three years, with a total loss in 1912. For the three years that the wheat was sown in the standing cornstalks, the spring survival was much higher. Table XI shows the annual and average yields of seven varieties of winter wheat grown during the six years from 1909 to 1914, inclusive.

TABLE XI.—*Annual and average yields of seven varieties of winter wheat grown at the Williston substation, 1909 to 1914, inclusive.*

C. I. No.	Variety.	Yield per acre (bushels).						
		1909	1910	1911	1912 ¹	1913	1914	Average.
1543.....	Beloglina.....	40.0	9.9	26.5	0	7.8	10.0	15.7
3084.....	North Dakota No. 1997.....	26.6	7.3	28.7	0	13.1	15.8	15.3
1583.....	Kharkof.....	29.9	7.3	24.9	0	6.8	.....	13.8
3011.....	Eversole.....	21.6	9.1	24.9	0	8.4	.....	12.8
3696.....	Grafton.....	19.9	7.2	26.1	0	.....	.....	13.3
3699.....	Reliable.....	.....	8.7	18.2	0	7.1	.....	8.5
3330.....	Buffum No. 17.....	.....	.....	.....	0	15.6	17.1	16.4
	Average.....	27.6	8.3	24.9	0	9.8	14.3	13.7

¹ The 1912 crop was entirely winterkilled.

The Beloglina (C. I. No. 1543) and an unnamed variety known as North Dakota No. 1997 (C. I. No. 3084) have been found to be the hardiest and best yielding varieties at Williston for the entire period. Both these varieties are of the Crimean or Turkey group of hard red

winter wheats. They have bearded heads and white, glabrous glumes, except that North Dakota No. 1997 has become somewhat mixed and contains some plants with red glumes.

The Beloglina produced an average yield of 15.7 bushels for the six years, and North Dakota No. 1997 yielded 15.3 bushels per acre. The average yield is reduced because of the total killing of the 1912 crop. As previously stated, the plats were on bare ground that year. The Beloglina was sown also in another location between corn rows and the stalks left standing all winter. The spring survival of this plat was good and a yield of 35.1 bushels per acre was harvested. Substituting this yield in the year 1912, when there was no yield from the plat sown on bare ground, would raise the average yield for Beloglina from 15.7 to 21.6 bushels per acre for the six years.

Buffum No. 17 (C. I. No. 3330), introduced into the tests in 1913, gave a higher spring survival in 1913 and 1914 and a higher yield of grain than either Beloglina or North Dakota No. 1997. The heads of Buffum No. 17 are beardless and the glumes are glabrous. In appearance it resembles Ghirka Winter wheat (C. I. No. 1438). The other varieties have bearded smooth-chaffed heads.

With these results with winter wheat at Williston it would seem that a good spring survival can not be had unless the plants have some such protection as cornstalks or grain stubble. To seed on corn ground and leave the stalks standing is too expensive where the corn fodder is valued as highly as it is in the Williston district.

In date-of-seeding trials of winter wheat at Williston it has been found that seeding about the middle of August gives better results than later seeding. If the stubble ground of some spring grain is used for the winter wheat, it is necessary to seed almost as soon as the grain crop can be removed. However, if the autumn is about normal in rainfall, there is likely to be insufficient moisture in the stubble land to germinate the seed.

NURSERY TESTS OF WINTER WHEAT.

Winter wheat has been tested in the nursery at Williston since 1911. Selections have been made from the varieties that have shown the hardiest qualities. Selections also were obtained from hardy varieties at the substations at Moccasin, Mont., and Newell, S. Dak.

Different methods were used in preparing the ground for seeding. Some sowings were made on bare ground, some in standing corn, some in grain stubble, and some by covering the rows lightly with straw. Whenever the rows were protected in any way by a covering of straw or snow, the winterkilling was very slight or there was none at all. Whenever the rows remained without covering, most or all of the plants were killed.

EXPERIMENTS WITH OATS.

The annual and average yields of the varieties of oats that have been grown in plat tests at Williston for the seven years from 1908 to 1914, inclusive, are presented in Table XII. The varieties are grouped in the table according to their date of maturity, the groups being early, midseason, and late. The midseason group is further separated into white, yellow, and black varieties. Of the 38 varieties included in the table, only 17 were grown in 1914.

TABLE XII.—*Annual and average yields per acre of 38 varieties of oats grown at the Williston substation, 1908 to 1914, inclusive.*

Group, Cereal Investigations number, and variety.	Yield per acre (bushels).							Average.
	1908	1909	1910	1911	1912	1913	1914	
Early yellow group:								
459, Kherson.....							78.9	
165, Sixty-Day.....	28.8	76.3	4.2	11.2	50.3	45.0	82.2	42.6
165, Sixty-Day (N. Dak. No. 666).....	22.3							
Midseason white group:								
731, Abundance (N. Dak. No. 966).....	31.3	91.1	12.5	7.7	104.7	93.4	123.9	66.4
Abundance (N. Dak. No. 866).....	15.3							
336, Belyak (N. Dak. No. 1425).....	14.3	84.0	12.0	6.1	63.8			36.0
733, Big Four (N. Dak. No. 38).....	28.0	99.3	9.4	10.0	91.3	62.8		50.1
Big Four (N. Dak. No. 125).....	17.9							
444, Canadian.....						51.2		
734, Early Gothland (Minn. No. 26).....	16.4	83.6	13.0	6.1	96.0			43.0
754, Early Mountain.....						62.5	96.1	79.3
491, Hvitling.....	29.6	80.6	12.5	9.6	105.0			47.5
736, Hvitling.....					62.2	58.5	92.2	71.0
492, Ligowo.....	30.4	104.1	3.6	8.9	98.8			49.2
737, Ligowo (N. Dak. No. 53).....	28.3	83.3	9.9	7.7	105.0	76.5		51.8
738, Lincoln (N. Dak. No. 48).....	32.1	96.2	15.6	7.0	101.3	84.5	124.3	65.9
Lincoln.....	14.3							
745, Minnesota No. 202 (N. Dak. No. 802).....	28.0	89.2	12.0	7.6	103.2	80.6		53.4
739, Myrick (N. Dak. No. 52).....	27.3	90.4	8.9	10.0	107.8	82.5	102.3	61.3
741, Siberian (N. Dak. No. 864).....	29.0	104.1	10.9	5.1	106.9	79.4	116.4	64.5
714, Silvermine (N. Dak. No. 723).....	37.4	103.3	14.8	7.3	95.7	67.5	120.7	63.8
134, Swedish Select.....	28.4	86.0	7.8	9.9	84.4	68.8	97.3	54.7
Do.....						66.3		
742, Victory.....					88.2	75.6	95.2	86.3
743, White Waverly (N. Dak. No. 997).....	11.3	68.0	8.3	5.7	84.4			35.6
Midseason yellow group:								
735, Golden Cluster (N. Dak. 1084).....	13.3	104.0	7.8	4.8	108.2	84.5		53.8
493, Golden Rain.....	14.9						123.3	69.1
494, Probsteler.....	14.9							
495, Probsteler.....	36.1	95.0	9.4	6.1	101.3	72.0	112.8	61.8
Midseason black group:								
Black Beauty.....			9.4	1.3				
766, Black Beauty.....							82.0	
496, Black Bell.....	23.8							
497, Great Mogul.....	23.4							
Late white (side oats) group:								
740, New Zealand (N. Dak. No. 50).....	36.1	86.4	8.9	3.5	106.2	82.8		54.0
713, Tartarian (N. Dak. No. 388).....	21.4	67.4	11.5	1.3	118.8	83.1	66.8	52.9
732, White Russian (N. Dak. No. 51).....	23.0	70.8	13.0	2.9	120.6	80.3	102.0	58.9
744, White Russian (N. Dak. No. 54).....	20.6	79.0	11.0	2.2	103.2	76.3	102.4	56.4
White Russian (N. Dak. No. 238).....	12.6							

In 1908 and 1911 the oats were seeded on ground that had produced small grain the previous year. In all other years they were grown either on breaking or fallow. The ground each spring was worked into good condition before seeding by harrowing alone or by disking and harrowing.

The seeding was at a rate of 8 pecks per acre from 1908 to 1912, inclusive, 6 pecks per acre in 1913, and 4 pecks per acre in 1914. The rate-of-seeding tests at Williston have shown that the best rate at which to sow oats in that locality is between 4 and 6 pecks per acre. The oats have not been treated for smut every year before seeding, but only when indications of smut were noted.

The only early variety which has been grown more than one year is the Sixty-Day. By far the greater part of the oats grown at Williston belongs to the group here designated as midseason white varieties. These varieties have also produced the best yields. They are decidedly variable as to size of panicle, size and shape of kernel, and other characters, but these differences are not apparent enough to justify further subdivisions into groups at this time.

Of the midseason yellow varieties, only the Probsteier has been grown for the full period, while none of the black oats has been included in the test for more than two years. The late varieties grown at Williston all have one-sided panicles. They have been exceeded in yield by several open-panicled varieties of midseason white oats.

SUMMARY OF OAT YIELDS.

The annual and average yields, the average dates of heading and ripening, the height, and the weight per bushel of the 11 varieties of oats which have been grown for seven years (1908 to 1914) at the Williston substation are shown in Table XIII. The yields are also shown graphically in figure 8. The varieties are arranged in the table and in the graph in the order of their average yields.

Of the varieties included in Table XIII, one (Sixty-Day) may be classed as early, three as late, and the remaining seven as medium or midseason varieties. Heads of four representative varieties are shown in figure 9.

EARLY VARIETIES.

The only early variety of oats which has been grown for the full seven years at Williston is the Sixty-Day (C. I. No. 165). This variety was originally imported from southern Russia by the United States Department of Agriculture in 1901. A similar variety, the Kherson, was imported a few years earlier from the same region by the Nebraska experiment station. The Sixty-Day and Kherson oats are now grown extensively in the corn belt and in the semiarid por-

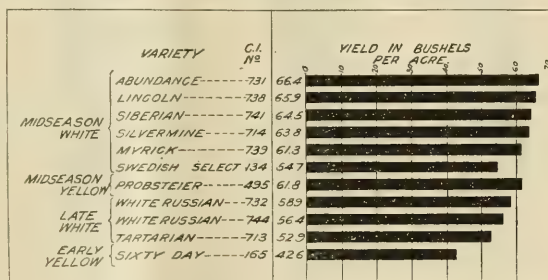


FIG. 8.—Diagram showing the average yields of eleven varieties of oats at the Williston substation, 1908 to 1914, inclusive.

tions of the United States. At Williston, however, they have given far lower yields than the other varieties under test, and there is no good reason for recommending them for this district unless a very early variety is desired.



FIG. 9.—Heads of four varieties of oats grown at the Williston substation (left to right): 1, White Russian; 2, Siberian; 3, Swedish Select; 4, Sixty-Day.

TABLE XIII.—*Annual and average yields, growth data, and weight per bushel, by groups, of eleven varieties of oats grown at the Williston substation, 1908 to 1914, inclusive.*

Group, Cereal Investigation number, and variety.	Yield per acre (bushels).								Date headed.	Date ripe.	To maturity from—		Height.	Weight per bushel.
	1908	1909	1910	1911	1912	1913	1914	Average.			Planting.	Heading.		
Midseason white:											Days	Days	In.	Lbs.
731, Abundance.....	31.3	91.1	12.5	7.7	104.7	93.4	123.9	66.4	July 11	Aug. 4	102	24	36	26.1
738, Lincoln.....	32.1	96.2	15.6	7.0	101.3	84.5	124.3	65.9	July 10	do.....	102	25	36	27.7
741, Siberian.....	23.0	104.1	10.9	5.1	106.9	79.4	116.4	64.5	July 11	do.....	102	24	37	30.7
714, Silvermine.....	37.4	103.3	14.8	7.3	95.7	67.5	120.7	63.8	July 10	Aug. 3	102	24	35	32.0
739, Myrick.....	27.3	99.4	8.9	10.0	107.8	82.5	102.3	61.3	July 11	Aug. 5	103	25	35	29.7
134, Swedish Select.	28.4	86.0	7.8	9.9	84.4	68.8	97.3	54.7	July 9	Aug. 2	101	24	36	30.7
Midseason yellow:														
495, Probsteler.....	36.1	95.0	9.4	6.1	101.3	72.0	112.8	61.8	July 11	Aug. 5	102	25	36	31.0
Late white:														
732, White Russian	23.0	70.8	13.0	2.9	120.6	80.3	102.0	58.9	July 15	Aug. 9	107	25	38	30.4
744, White Russian	20.6	79.0	11.0	2.2	103.2	76.3	102.4	56.4	do.....	do.....	107	25	38	30.9
713, Tartarian.....	21.4	67.4	11.5	1.3	118.8	83.1	66.8	52.9	do.....	Aug. 6	106	22	37	29.3
Early yellow:														
165, Sixty-Day.....	28.8	76.3	4.2	11.2	50.3	45.0	82.2	42.6	June 29	July 24	89	25	29	30.0

MIDSEASON VARIETIES.

Seven of the eleven varieties under discussion may be classed as medium in maturity. The average date of ripening of these varieties for the seven years ranges from August 2 to 5, 101 to 103 days being required from seeding to maturity. Six of these varieties have yielded more than any of the early or late oats, while the seventh, Swedish Select, has yielded less than the two stocks of White Russian. All are open-panicked varieties and all have white hulls except Probsteyer, which is yellowish white.

The farmer in the locality of Williston who grows any of these varieties, with the possible exception of Swedish Select, will make no mistake. The average yields here reported show that there is little choice between them, though Abundance, Lincoln, Siberian, and Silvermine have slightly exceeded the others in average yield, due in part to their extremely high yields in 1914. The weight per bushel of the Silvermine is higher than that of any of the other varieties in the test.

LATE VARIETIES.

The White Russian and Tartarian are very similar, if not identical, varieties of late oats. They mature about August 6 to 9 at Williston, requiring from four to six days more from seeding to maturity than the midseason varieties just discussed. The heads are long, compact, and turned to one side (side, or horse-mane, oats). The kernels are white, long, and slender. In favorable seasons they usually yield well, but in ordinary or particularly unfavorable years they usually fall far below the earlier varieties.

The 7-year average yield of the best White Russian (C. I. No. 732) is $7\frac{1}{2}$ bushels lower than that of Abundance, the best open-panicked variety. Both stocks of White Russian have yielded more than the Tartarian, though the difference is largely due to the low yield of the latter in 1914. The yield of the Tartarian was low in 1914 because of poor germination and the poor stand which resulted.

Except where large acreages of oats are grown, so that it is desirable to have the maturity of the crop extend over a considerable period to prevent losses in harvesting, the growing of side oats in this district is not recommended.

RATE-OF-SEEDING TEST WITH OATS.

A rate-of-seeding test with oats has been conducted for four years (1911 to 1914) at Williston. The Swedish Select variety has been used in this test, in which the rates of seeding were 2, 4, 6, 8, and 10 pecks. The 10-peck rate of seeding was discontinued in 1914. The results of this experiment are shown in Table XIV.

TABLE XIV.—*Annual and average yields in a rate-of-seeding test of Swedish Select oats at the Williston substation, 1911 to 1914, inclusive.*

Rate of seeding.	Yield per acre (bushels).				
	1911	1912	1913	1914	Average.
2 pecks.....	3.5	76.9	38.8	82.2	50.4
4 pecks.....	6.0	70.0	73.8	97.3	61.8
6 pecks.....	6.4	53.7	78.1	108.2	61.6
8 pecks.....	7.3	60.0	75.6	111.4	63.6
10 pecks.....	10.8	64.4	73.0	.....	.....

The highest average yield, 63.6 bushels, as shown in Table XIV, has been obtained from the 8-peck rate. This yield, however, is only slightly higher than was obtained from the 4-peck and 6-peck rates, and when the extra bushel of seed required is taken into account it exceeds the 4-peck rate by only 0.8 bushel.

Attention is called to the fact that three of the four years during which the test has been conducted have been favorable ones for crop production and that one of them (1914) was particularly favorable for oats. Experiments elsewhere in the Great Plains have shown that the higher rates of seeding for the various cereals usually give best returns in favorable years, but that in ordinary or unfavorable years the lower rates are better. If the particularly favorable year (1914) is disregarded, the average yield from the 4-peck rate at Williston for the preceding three years is about 3 bushels higher than from either of the higher rates. At present, therefore, it appears to be advisable to recommend sowing from 4 to 6 pecks of oats to the acre in the Williston district. This test will be continued and the results reported at a later date.

EXPERIMENTS WITH BARLEY.

Practically all the varieties of barley which have been grown at Williston have been of the ordinary hulled (common) class, though two naked (hull-less) varieties have been included in the tests. All the varieties, with the exception of Nepal, are bearded. About two-thirds of the hulled varieties are 6-rowed and one-third 2-rowed. The annual and average yields of the 26 varieties and races of barley which have been grown at Williston for the seven years from 1908 to 1914 are given in Table XV. Of these 26 varieties only 14 were tested in 1914, the others having been discarded previously.

LEADING VARIETIES.

As shown in Table XV, the yields of only six varieties of barley are available for the full period of seven years. Of these, four are 6-rowed and two are 2-rowed barleys. All are bearded and all are hulled (common) varieties. The few naked and hooded varieties which have been grown at Williston have produced very low yields.

TABLE XV.—*Annual and average yields of 26 varieties of barley grown at the Williston substation, 1908 to 1914, inclusive.*

	Yield per acre (bushels).							
Group, Cereal Investigations number, and variety.	1908	1909	1910	1911	1912	1913	1914	Aver- age.
Six-rowed hulled group:								
881, Bernard (N. Dak. No. 789).....	17.1	52.1	5.7	9.8	62.9	40.0	53.9	34.5
575, Gatami.....			7.3	19.5	59.2	(1)	53.2	34.8
638, Manchuria (Minn. No. 6).....	15.7	57.0	8.1	6.6	74.0	44.8	53.2	37.1
643, Manchuria (Minn. No. 105).....	14.2	49.4	6.7	11.0	71.5	37.1	65.1	36.4
739, Manchuria.....					58.3	46.3	76.6	60.4
879, Manchuria (Minn. No. 32).....	13.7	50.3	3.8	5.7	59.8			26.7
880, Manchuria (Minn. No. 87).....	9.8	51.3	2.6	8.5	56.9			25.8
885, Manchuria (N. Dak. No. 172).....	6.4	56.0	2.0	8.1	51.2			24.7
886, Manchuria (N. Dak. No. 252).....	9.5	51.9	5.1	9.8	63.1			27.9
887, Manchuria (N. Dak. No. 871).....	13.3	53.5	4.5	10.2	60.8	(1)	52.4	32.5
888, Oderbrucker.....		55.6	3.7	7.7	61.3	49.8	52.9	38.5
889, Read Triumph.....		46.8	2.2	5.1	61.5	51.8		33.5
...., Russian (N. Dak. No. 107).....	11.3	57.8	3.9	4.3	60.6			27.6
890, Silver King (N. Dak. No. 719).....	12.0	57.2	4.7	7.7	63.1	35.4		30.0
882, Williston No. 170 (N. Dak. No. 966).....	18.2	53.7	6.7	12.3	65.5	51.3	71.3	39.9
Average of 6-rowed hulled.....	12.8	53.3	4.1	9.0	62.0	44.6	59.8	.....
Two-rowed hulled group:								
740, Canadian Thorpe.....					50.0			
203, Hanna (N. Dak. No. 649).....	10.0	56.0	3.9	10.6	65.8	19.6	66.7	33.2
531, Hannchen.....						26.2	72.9	49.6
883, Highland Chief (N. Dak. No. 847).....	10.6	47.8	2.4	5.5	66.6	24.0		26.1
532, Primus.....							63.6	
893, Proskowetz.....						25.8	54.7	40.3
891, Success (N. Dak. No. 171) ²	11.3	46.0	1.2	8.5	68.3	26.9	48.5	30.1
187, Svanhals.....							53.7	
Average of 2-rowed hulled.....	10.6	49.9	2.5	8.2	62.7	24.7	60.2	.....
Six-rowed naked group:								
884, Nepal ³		33.3	1.4	6.5	41.7			20.7
Two-rowed naked group:								
892, McEwan (N. Dak. No. 149) ³			3.6	5.8	36.0			15.1
Summary of averages:								
Six-rowed hulled.....	12.8	53.3	4.1	9.0	62.0	44.6	59.8	.....
Two-rowed hulled.....	10.6	49.9	2.5	8.2	62.7	24.7	60.2	.....
Six-rowed naked.....		33.3	1.4	6.5	41.7			.....
Two-rowed naked.....			3.6	5.8	36.0			.....

¹ Record lost.² This variety is distinct from the 6-rowed hooded hulled variety commonly known as Success, for which the name Horsford is preferable.³ Yields in bushels of 60 pounds; yields of other varieties in bushels of 48 pounds.

The annual and average yields, the average dates of heading and ripening, height, yield per acre, and weight per bushel of these six varieties are shown in Table XVI. In this table the varieties are arranged according to their average yields for the 7-year period. These yields are shown graphically in figure 10. Figure 11 shows heads of representative varieties of three different groups of barley grown at Williston.

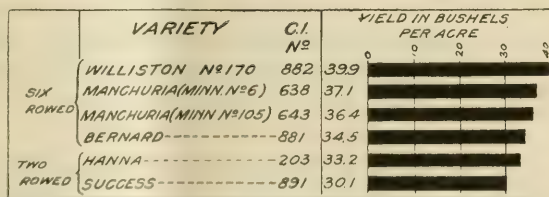


FIG. 10.—Diagram showing the average yields of six varieties of barley at the Williston substation, 1908 to 1911, inclusive.

The average annual yield of the four 6-rowed barleys has been greater in each of the seven years than the average annual yield of the two 2-rowed varieties (Table XVI). The average yield for the entire period is 37 and 31.6 bushels, respectively. Quite different results



FIG. 11.—Heads of three varieties of barley grown at the Williston substation: 1, Manchuria; 2, Svanhals; 3, Hannchen.

were obtained at the Dickinson substation, where the 2-rowed varieties considerably exceeded the 6-rowed in yield.¹

SIX-ROWED VARIETIES.

All the 6-rowed varieties listed in Table XVI are very similar in appearance. They all belong to the Manchuria group, which is the barley commonly grown in Wisconsin and Minnesota.

The highest average yield for the 7-year period (1908 to 1914), 39.9 bushels, has been produced by the Williston No. 170 (C. I. No. 882),

¹ Clark, J. A. Cereal Experiments at Dickinson, N. Dak. U. S. Dept. Agr. Bul. No. 33, 1914, p. 31-36.

an unnamed variety of the Manchuria group grown locally near Williston. Since 1910, as noted in Table XVI, the yields reported are for a pure-line selection from the original stock of Williston No. 170. The average yields of two lots of Manchuria (Minn. No. 6, C. I. No. 638, and Minn. No. 105, C. I. No. 643) for the seven years are 37.1 and 36.4 bushels, respectively.

The Bernard (C. I. No. 881) is another local variety similar to Manchuria. The average yield of this variety for the seven years is considerably lower than that of the others here reported.

TABLE XVI.—*Annual and average yields, growth data, and weight per bushel of six standard varieties of barley grown at the Williston substation, 1908 to 1914, inclusive.*

Group, Cereal Investigations number, and variety.	Yield per acre (bushels).							Date headed.	Date ripe.	To maturity from —		Height.	Weight per bushel.
	1908	1909	1910	1911	1912	1913	1914			Planting.	Heading.		
Six-rowed:										<i>Days.</i>	<i>Days.</i>	<i>In.</i>	<i>Lbs.</i>
882, Williston No. 170 ¹	18.2	53.7	6.7	12.3	65.5	51.3	71.3	July 5	July 26	88	21	34	45.4
638, Manchuria (Minn. No. 6).....	15.7	57.0	8.1	6.6	74.0	44.8	53.2	July 6	do....	88	20	32	44.9
643, Manchuria (Minn. No. 105).....	14.2	49.4	6.7	11.0	71.5	37.1	65.1	do....	do....	88	20	32	46.6
881, Bernard.....	17.1	52.1	5.7	9.8	62.9	40.0	53.9	do....	July 25	87	19	33	46.6
Average.....	16.3	53.1	6.8	9.9	68.5	43.3	60.8						
Two-rowed:													
203, Hanna.....	10.0	56.0	3.9	10.6	65.8	19.6	66.7	July 10	July 27	90	17	27	47.7
891, Success.....	11.3	46.0	1.2	8.5	68.3	26.9	48.5	July 15	Aug. 2	96	18	26	47.2
Average.....	10.7	51.0	2.6	9.6	67.1	23.3	57.6						

¹ In 1910 and succeeding years the yields reported are those obtained from a pure-line selection from the original Williston No. 170, a variety of the Manchuria group.

The average date of maturity of the 6-rowed varieties, as shown in Table XVI, is July 26, which is one day earlier than that of Hanna and seven days earlier than that of Success, the two 2-rowed varieties. The average height of the 6-rowed varieties, 32 to 34 inches, is several inches more than that of the 2-rowed varieties, an important matter in dry-land farming, where barley and other grain is sometimes too short to harvest with the binder. In weight per bushel the 2-rowed varieties have exceeded the 6-rowed, the average weight of the former being 47.2 to 47.7 pounds, while the four 6-rowed varieties vary from 44.9 to 46.6 pounds.

TWO-ROWED VARIETIES.

The two 2-rowed varieties, Hanna (C. I. No. 203) and Success (C. I. No. 891), as already stated, show a lower average yield for the seven years than any of the four 6-rowed varieties included in Table XVI. The average yield for Hanna is 33.2 bushels and for Success 30.1 bushels. The Hanna has yielded more than the Williston No. 170 in

only two of the seven years, and in these two years the differences were very slight. It has also yielded more than the Manchuria (C. I. No. 638) in only two years, 1910 and 1914, but in both cases the difference has been considerable. The Success has yielded more than Williston No. 170 and Manchuria (C. I. No. 638) in only one of the seven years.

The unsatisfactory yields of the 2-rowed varieties may be due in part to an unfortunate choice of varieties. However, their performance thus far does not warrant recommending them for this section or describing them in detail in this bulletin.

NURSERY TESTS OF BARLEY.

A considerable number of varieties and stocks of barley have been grown in the nursery at Williston. All the varieties grown in the field plats, as well as a number of others, were grown in the nursery. The greater part of these varieties, as in the field tests, were 6-rowed and 2-rowed bearded hulled barleys, but 2-rowed and 6-rowed bearded naked and 6-rowed hooded naked varieties were also included.

The number of varieties in each class, with the average number of days from seeding to maturity, height, length of head, number of stools and of heads per plant, weight of 1,000 kernels, and weight of straw and of grain from a rod row for each class in 1912 and 1913 are shown in Table XVII.

TABLE XVII.—Average miscellaneous data for the various classes of barley grown in the nursery at the Williston substation in 1912 and 1913.

Class.	Number of races.	Days to maturity.	Height.	Length of head.	Stools per plant.	Heads per plant.	Weight of 1,000 kernels.	Yield from rod row.	
								Straw.	Grain.
Bearded hulled:			<i>Inches.</i>	<i>Inches.</i>			<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Six-rowed.....	30	91	29.5	2.50	7.59	5.90	40.5	521	459.5
Two-rowed.....	27	92	29.0	3.15	9.50	7.46	45.1	589	430.9
Bearded naked:									
Six-rowed.....	9	86	25.3	2.35	7.39	5.30	37.7	514	362.1
Two-rowed.....	5	85	24.1	2.41	7.32	5.44	49.8	513	372.1
Hooded naked:									
Six-rowed.....	3	87	30.0	2.59	6.77	4.40	45.1	522	348.2

The naked varieties, as shown in Table XVII, mature somewhat more quickly and, with the exception of the hooded forms, have shorter straw than the hulled varieties. The 2-rowed hulled varieties stool more freely and produce more and longer heads than those of any of the other classes. The weight of 1,000 kernels is greatest for the 2-rowed naked varieties, exceeding that of the 2-rowed hulled by 4.7 grams. The yield of straw per row was greatest from the 2-rowed hulled class, while the yield of grain was largest from the 6-rowed hulled varieties.

EXPERIMENTS WITH FLAX.

The yields obtained from the varieties of flax that have been tested at Williston are shown in Table XVIII. In 1908 the flax was sown on ground that produced oats the previous year. In 1909, 1910, and 1912 the flax varieties were tested on breaking. In 1911 they were on ground that was planted to corn the previous year, but that crop was destroyed by hail in August. In 1913 and 1914 the varieties were sown on fallow ground. In both these years the plats were so overgrown with Russian thistles that the yields were not considered comparable and hence are not reported.

TABLE XVIII.—*Annual and average yields of six varieties of flax grown at the Williston substation, 1908 to 1912, inclusive.*¹

C. I. No.	Variety.	Yield per acre (bushels).				
		1908	1909	1910	1912	Average.
16	North Dakota No. 1221.....	8.5	23.5	5.4	27.5	16.2
17	North Dakota No. 155.....	7.4	22.4	6.5	26.8	15.8
18	North Dakota No. 1133.....	7.8	21.7	5.2	27.2	15.5
10	Primost.....		14.2	3.6	23.9	
8	North Dakota Resistant No. 52.....				30.0	
12	Primost.....				19.7	

¹ These varieties were grown in 1913 and 1914, but the plats were so overgrown with Russian thistles that comparable yields could not be obtained.

The average yields of the three lots of flax that have been grown for the four years (1909 to 1912) are practically the same, ranging from 15.5 to 16.2 bushels. In 1912 the race known as North Dakota Resistant No. 52, which was included in the tests for the first time that year, produced the highest yield.

EXPERIMENTS WITH MINOR CEREALS.

Experiments with the minor spring cereals at Williston have included three varieties of emmer, one of rye, one of spelt, one of proso, and one of millet. While emmer has given good yields for most of the six years tested, it has not proved to be a better crop than barley. Table XIX presents the annual and average yields for six years (1909 to 1914) of one variety of emmer and one of rye with those of standard varieties of durum and common wheat and of oats and barley for comparison. The average yields per acre are given in pounds as well as bushels, so that the comparison can be made more readily.

Table XIX shows that oats produced more pounds of grain per acre than the best varieties of wheat, barley, emmer, and rye. The average yield of Siberian oats for the six years was 2,256 pounds to the acre; of Kubanka durum and Power life wheat, 1,968 and 1,872 pounds, respectively; of Manchuria barley (Williston No. 170), 2,088 pounds; of emmer, 1,580 pounds; and of rye, 1,377 pounds.

TABLE XIX.—*Annual and average yields of six varieties of cereals grown at the Williston substation, 1909 to 1914, inclusive.*

C. I. No.	Variety and cereal.	Yield per acre.							
		1909	1910	1911	1912	1913	1914	Average.	
1440	Kubanka durum wheat.....	<i>Bush.</i> 31.9	<i>Bush.</i> 11.0	<i>Bush.</i> 8.9	<i>Bush.</i> 51.0	<i>Bush.</i> 33.0	<i>Bush.</i> 53.8	<i>Bush.</i> 32.8	<i>Lbs.</i> 1,968
3697	Power five wheat.....	34.0	17.1	11.1	44.7	28.7	51.3	31.2	1,872
741	Siberian oats.....	104.1	10.9	5.1	106.9	79.4	116.4	70.5	2,256
882	Williston No. 170 barley.....	53.7	6.7	12.3	65.5	51.3	71.3	43.5	2,088
	North Dakota No. 305 emmer.....	54.4	11.3	3.8	79.5	43.0	44.9	39.5	1,580
169	Spring rye.....	40.0	6.1	9.1	43.6	16.3	32.3	24.6	1,377

The stand of the North Dakota No. 305 emmer in 1914 was very thin; hence, the yield was abnormally low. For this reason the comparison of average yields for the six years shown in Table XIX is somewhat unfair to the emmer. White spring emmer grown on an adjoining plat yielded 85 bushels to the acre. If this yield is substituted for that of the North Dakota No. 305 in the table, the average yield is increased to 1,847 pounds. White spring spelt (C. I. No. 2968) was grown only in 1914, when it yielded 70.6 bushels to the acre. Since the grains of emmer and spelt remain in the glumes after thrashing, they are more comparable to oats and barley than to wheat and rye. The yields here reported indicate that it is not advisable to substitute spring emmer or spelt for oats or barley as a feed grain in the Williston district.

In 1912, 1913, and 1914 Black Voronezh proso (C. I. No. 16) was grown in field plats. The yields of grain for the three years were 24, 22.1, and 29 bushels per acre, respectively.

In 1914 Kursk millet was also tested in a field plat, producing a yield of 38 bushels of seed per acre, 9 bushels more than the Black Voronezh proso for the same year.

In prosos the seeds ripen first at the tips of the heads. The crop may be cut when most of the head is ripe and the tip begins to shatter. The straw and leaves are still green at this stage, but the shocking may be done so as to permit perfect curing without molding. A fair quality of hay remains after the seed is thrashed out.

Grain sorghums, especially early kaoliangs, have been tried at Williston, but thus far have matured little grain. The grain sorghums do not compare favorably in this district with the best varieties of corn.

SUMMARY.

Cooperative experiments with cereals at the Williston substation have been conducted for the seven years from 1908 to 1914, inclusive.

The Williston substation is located in the extreme southern part of Williams County, in northwestern North Dakota, at an altitude of approximately 1,900 feet.

The average annual precipitation at Williston for the 36 years from 1879 to 1914, inclusive, was 14.9 inches. The average seasonal rainfall (April to July, inclusive) for these years was 8.86 inches. The heaviest rainfall at Williston occurs during the growing season.

The average evaporation from a free water surface at the Williston substation during the growing season for the years 1909 to 1914, inclusive, was 24.03 inches. The average precipitation for the same period was 8.43 inches.

The average wind velocity per hour during the months from April to July, inclusive, for the years 1909 to 1914, inclusive, was 6.6 miles.

The average length of the frost-free period for the 33 years has been 119 days. The average date of the last killing frost in the spring has been May 18 and of the first killing frost in the fall, September 14.

The soil at the Williston substation on which the cereal varieties have been tested consists of a fine sandy loam.

The varietal tests on plats have included 36 varieties and strains of spring wheat, 40 of oats, 27 of barley, and a few each of flax, emmer, spelt, rye, proso, and winter wheat.

Spring wheats have given better results than winter wheats.

Except in the dry years, 1910 and 1911, the durum wheats have produced higher yields than the common spring wheats.

Kubanka durum wheat (C. I. No. 1440) gave the highest average yield of all of the spring wheats tested from 1908 to 1914, inclusive, 29.9 bushels per acre. Power fife wheat (C. I. No. 3697) stood second for the same period, producing 28.6 bushels per acre.

The bluestem group has not yielded as well as the durums and fifes, and the average weight per bushel has also been lower.

Rate-of-seeding tests with bluestem spring wheat have indicated that the highest yields are obtained from sowing 4 pecks to the acre.

The average yields from winter wheat are lower than those from the spring wheats, for winter wheat frequently winterkills. Sowing winter wheat in grain stubble or standing corn gives protection to the plants and reduces the loss from winterkilling.

The best three varieties of oats for the seven years, 1908 to 1914, are Abundance, with an average yield of 66.4 bushels per acre; Lincoln, 65.9 bushels; and Siberian, 64.5 bushels. These are all midseason varieties. The late-maturing varieties, such as White Russian, and the very early varieties, Sixty-Day and Kherson, have yielded much less than the midseason varieties.

Rate-of-seeding tests with Swedish Select oats indicate that the best yields are obtained by sowing from 4 to 6 pecks per acre.

The 6-rowed group of barley has yielded better than the 2-rowed group. The highest average yield for the seven years (1908 to 1914),

39.9 bushels, has been produced by the Williston No. 170 (C. I. No. 882), a strain of Manchuria barley.

Flax is grown with some difficulty on ground that is infested with weeds. In the seven years that tests were made, only four crops were harvested. The average yield of the highest producing variety for these four years was 16.2 bushels per acre from the North Dakota No. 1221 (C. I. No. 16).

Emmer and spring rye have not given as high average yields as oats, barley, or wheat.

Proso, grown in field plats from 1912 to 1914, inclusive, gave an average yield of seed per acre of 25 bushels. Kursk millet, grown in a plat test in 1914, yielded 38 bushels of seed per acre.





BULLETIN No. 271

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Wm. A. Taylor, Chief.



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PROFESSIONAL PAPER

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DATES OF EGYPT AND THE SUDAN.

By S. C. MASON,

Arboriculturist, Crop Physiology and Breeding Investigations.

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INTRODUCTION.

The earliest importation of date offshoots into the United States (a lot of 59 received through correspondence by the Department of Agriculture in July, 1890) was from Egypt.

Eleven years passed before Mr. David Fairchild, Agricultural Explorer, of the Bureau of Plant Industry, visited Egypt and obtained offshoots of a number of the leading varieties. Small lots of Egyptian offshoots were secured through agents in later years, but the fact remained that the dates of Egypt, of which there are more than 7,000,000 trees, were less thoroughly known to American experimenters than those of any other great date-producing region. In the published lists of Egyptian dates there was much confusion and contradiction, and the identity of some of the more promising of the Egyptian varieties on trial at the Tempe and Mecca date gardens was in doubt.

These considerations induced the offices of Crop Physiology and Breeding Investigations and of Foreign Seed and Plant Introduction to combine in sending the writer to Egypt and the Sudan in August, 1913. An account of the journey in these countries, from August, 1913, to February, 1914, is embodied in another paper, but the descriptions of 22 varieties of dates of Egypt and the Sudan, comprising most of the commercial dates of those regions, as well as of several varieties of minor importance not heretofore published, are assembled in this bulletin.

The purchase of offshoots of the most desirable varieties was effected through the courtesy of Egyptian and Sudan officials, to whom the Department of Agriculture is also indebted for much important information bearing upon cultural conditions.

The analyses of the official weather records of Egypt and the division of the Nile Valley into three zones in accordance therewith throws much new light on the culture of dates in general and especially upon the behavior of the groups of varieties under consideration.

NILE VALLEY DATES AND THEIR CLIMATIC ENVIRONMENTS.

No one would venture to declare the age of date culture in Egypt, but from the intercourse which the Egyptians are known to have had with the neighboring date-growing lands at a very remote time, there can be little doubt that the Egyptian people cultivated the date at an early day. In the great Hall of Columns at Karnak, attributed to the nineteenth dynasty, or 1,370 years B. C., many of the columns are clearly modeled from a date tree, the capital being the spreading leaves as they appear from beneath. We can hardly doubt that date groves flourished then in the rich Nile lands even as they do to-day.

With the more than 7,000,000 date trees growing in Egypt to-day, their product does not suffice for the wants of 11,000,000 people.¹ There is a small exportation of dates to Europe from the delta, chiefly of the Amri variety,² but this is more than offset by the importation of dates in fancy packages from Algeria and the Persian Gulf and by the shipments of dry dates from the Sudan, a considerable proportion of the date crop of Dongola Province finding its way down the river.

The dates described in the following paper comprise the chief commercial varieties of Egypt, including the western oases and the Sudan. The descriptions are from notes made in August to December, 1913, by the writer during a journey through the region described. Several varieties of minor importance which it is believed have not before been published are included.

The writer makes no pretense that this bulletin presents a complete list of Egyptian or Sudan varieties, which are exceedingly numerous, for little attempt has been made to secure the names even of the many seedling sorts which have received names and have been propagated in a small way by their originators. Of the

¹ The official census of the date trees for taxation in 1907 is 5,966,010. Trees in gardens and estates which pay a tax are not listed for separate taxation; also young trees under a certain minimum size are not listed for taxes. These two classes of exemptions would add very greatly to the actual number of date trees in the country. Sir William Willcocks estimated the total number of date trees in Egypt in 1899 at about 7,400,000, producing fruit annually valued at £1,480,000. This would make the value of the annual date crop a little below \$1 per tree.

² In the Annual Statistics of the Egyptian Ministry of Finance for 1912 the average yearly exportations of dates for the years 1905 to 1911 is given as 576,135 kilos, valued at £8,945, which would be, in round numbers, 1,267,000 pounds, at 3½ cents per pound.

6,000,000 date trees enumerated for taxation in Egypt, it is safe to assert that two-thirds are of the balady, or seedling, type of trees, of which the greater number produce fruit of low quality which is consumed by the poorer people in the immediate vicinity.

Among these, however, may occur occasional varieties of superior excellence, in rare instances ranking with any of the sorts now in cultivation. In a population of more advanced ideas in horticulture such varieties would be propagated to the utmost limit and their dissemination made as rapid as the slow nature of the date tree would admit. In Egypt such varieties are often confined to the garden in which they originated or to distribution among the immediate family of the owner. In one instance which came to the writer's knowledge a seedling variety not surpassed by any of the well-known sorts of Egypt was still confined to the garden where it originated, the property of a sheik of considerable wealth and position. The "mother" tree and five "daughters" have passed the age of producing offshoots. On a single "granddaughter" hangs the fate of this valuable variety.

The task of searching out such chance varieties of merit throughout Egypt would be an interminable one, but the results would doubtless repay the effort.

Date culture in Egypt and the Sudan extends with scarcely an interruption from the relatively cool Mediterranean coast up the Nile Valley to the burning desert heat of Aswan, and is paralleled in the Libyan oases of Fayum, Siwah, Baharieh, Farafreh, Dakhleh, and Khargeh. Above the first cataract, owing to the narrowing of the valley, the continuity of the date trees is a good deal broken, yet it may be considered a continuation of the culture through Ibrim, past Wadi Halfa, and up to the Sukkot region, around the great bow of the river past old Dongola, Merowe, Abu Hamed, and Berber to Khartum itself, where, entering the fringe of the great tropical rainy region, the limit of practical date culture to the southward is reached. (Pl. I.) This gives a north-and-south extent to the Nile Valley date culture of about 16 degrees of latitude, or approximately 1,100 miles, about equivalent to the distance from the mouth of the Mississippi River to Minneapolis and St. Paul. This is the longest continuous north-and-south extension of date growing to be found in the world, and it becomes of peculiar interest from the range of temperatures embraced and the differences in climatic conditions encountered. The difference in the mean annual temperature between Alexandria and Khartum amounts to about 15 degrees F., though the average difference for March, April, and May is over 21 degrees. This difference is not great when the difference in latitude is considered,¹ but

¹ The difference in mean annual temperatures between St. Paul and New Orleans, the similar distance previously cited, is about 25 degrees Fahrenheit.

when taken in connection with a fruit as exacting in temperature requirements as the date it becomes of very great importance.

Another important factor in the environment of the date tree is the relative humidity of the air, which along the Mediterranean coast, where there is an extensive culture, is very high throughout the year. At Alexandria, with a record of 23 years, the mean monthly range of relative humidity is from 64 to 72 per cent, with an annual mean of 68, some years running to 71 per cent. At Gizeh the mean relative humidity of a 10-year record is 69 per cent, with single monthly means as low as 50 and as high as 84 per cent. At Heluan the desert influences begin to be felt, and the mean relative humidity is reduced to 54 per cent, and at Siut (Assiut) it is 53 per cent. Aswan gives a record of 39 per cent humidity as a mean for 11 years, while the Oasis of Dakhleh, on a record of 7 years, shows real desert dryness, with a mean humidity of only 36 per cent, and Wadi Halfa, on a 20-year record, has the low mean of 34 per cent.

No weather records are available for the Sukkot region, formerly so important, but now superseded in the volume of date production by Dongola Province. Merowe, the capital of Dongola, fortunately has very complete records for recent years and shows the greatest dryness of any date region yet studied, its mean relative humidity for the year being only 24 per cent. For May, the driest month, the record is only 12 per cent on a 5-year mean; 30 per cent in August and 31 per cent in January, the most humid months.

Passing the fourth and fifth cataracts with considerable date culture in Berber Province, at the next weather station, Atbara Junction, influenced by the nearness of the rainy hill region on the east and southeast, the mean humidity rises to 38 per cent, reaching 50 per cent in August, with occasional records for April and May as low as 16 per cent. At Khartum, beyond which few date trees are found, the mean humidity for the year drops to 33 per cent.

For convenience in studying the character of the dates produced as related to their environment, the region under consideration may be divided as follows:

- (1) The maritime subtropical: Comprising Lower Egypt, or the Nile delta, including lower Gizeh.
- (2) The desert subtropical: Comprising Upper Egypt to Aswan, with the Libyan oases.
- (3) The desert tropical: Comprising Upper Egypt beyond Aswan and the Nile Valley in the Sudan at Khartum.

Hard and fast lines are difficult to draw, and if there were a greater number of observation stations it is probable that points on the margin of the delta toward the desert, like Salihieh and Korain on the eastern border of the delta and Manshia to the west of Gizeh, would show temperature and humidity conditions which would place them

in the desert zone rather than among maritime stations. The evidences of this in the record of 38 years at Abbasia, a military post in the unirrigated uplands in the northeast suburbs of Cairo, and in incomplete records at Ismailia on the Suez Canal are discussed in subsequent pages.

Table I gives the meteorological data for all the stations at which weather records are available in the three great climatic zones, with the characteristic date varieties for each type of climate.

MONTHS	DESERT TROPICAL				DESERT SUBTROPICAL				MARITIME SUBTROPICAL			
	KHARTUM	ATBARA	MEROME	WADI HALFA	DANHELEN OASIS	ASWAN	ASSIUT	HELIWAN	ABBASSIA	GIZEH	ALEXANDRIA	PORT SAID
JANUARY	30 71	24 68	29 68	47 59	47 56	52 58	69 71	62 72	71 74	86 87	54 56	76 80
FEBRUARY	25 75	20 72	24 72	37 62	42 59	45 59	63 65	56 55	67 67	76 75	57 54	59 59
MARCH	19 80	30 80	14 77	31 70	38 65	40 70	55 62	52 62	61 62	62 59	65 65	74 61
APRIL	20 86	23 84	14 83	25 79	32 75	34 78	43 79	45 71	53 69	60 67	67 65	73 65
MAY	22 89	25 89	12 80	21 81	29 89	36 89	37 89	41 79	50 76	56 76	66 70	73 70
JUNE	31 91	30 93	11 85	18 80	29 87	31 90	36 84	44 79	50 76	57 72	74 74	74 76
JULY	49 87	44 89	25 81	27 85	29 82	30 81	41 81	49 84	54 69	61 65	76 76	76 76
AUGUST	59 83	50 87	30 80	32 80	32 87	31 87	45 83	54 80	61 76	66 72	71 71	76 76
SEPTEMBER	50 87	45 81	22 80	34 80	35 80	36 80	58 79	58 78	69 76	72 75	68 77	74 78
OCTOBER	35 80	38 82	22 82	38 82	36 82	36 82	62 77	58 75	71 75	71 74	68 74	74 75
NOVEMBER	29 80	40 80	25 80	42 80	40 87	45 87	66 71	62 69	72 66	73 68	66 67	73 68
DECEMBER	32 73	42 70	31 70	60 62	46 58	49 58	66 56	64 56	70 58	70 55	68 60	76 60
MEAN	32 80	38 80	22 80	37 80	36 80	39 80	53 80	54 69	62 70	69 67	68 68	74 69

FIG. 1.—Diagrams showing the mean monthly relative humidity (in percentage of saturation, dark bars) and the mean monthly temperature (in °F., shaded bars) for 12 stations in Egypt and the Sudan.

Figure 1 shows the mean monthly relative humidity (in percentage of saturation) by the use of dark-faced bars and the mean monthly temperatures (in degrees Fahrenheit) by the use of tint-lined bars immediately below, in diagrammatic form, for twelve stations in Egypt and the Sudan.

Figure 2 shows by curves the mean monthly temperature (in degrees Fahrenheit) and the relation of the monthly mean to the assumed "zero point" (64.4° F.) of the date in flowering for the twelve weather-observing stations listed in Table I.

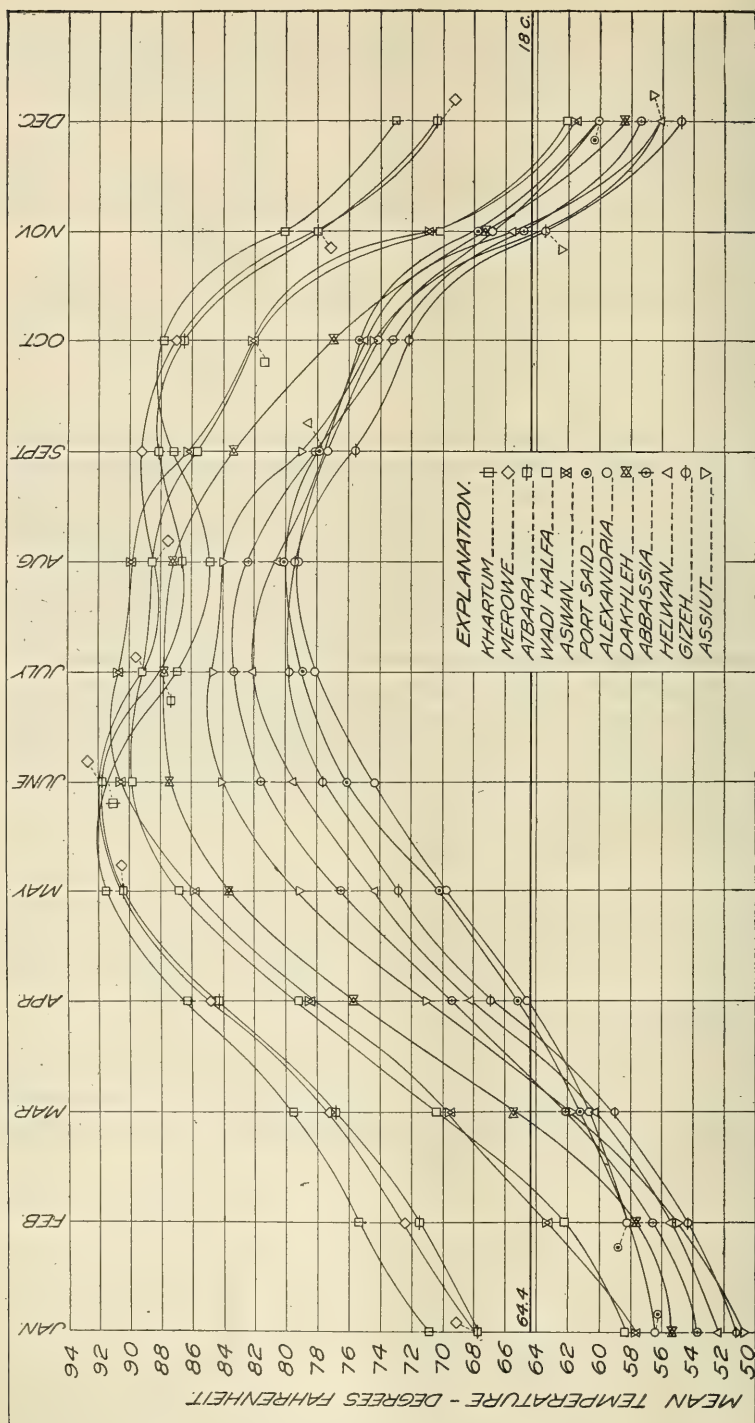


FIG. 2.—Curves showing the mean monthly temperatures in relation to the assumed “zero point” (64.4° F.) of the flowering of the date palm for 12 localities in Egypt and the Sudan.

TABLE I.—*Meteorological data for stations in the three great climatic zones of Egypt and the Sudan, showing the characteristic date varieties for each type of climate.*

Zone and locality.	Mean relative humidity.	Mean temperature (° F.).		Heat units above 64.4° F., May 1 to Oct. 31.	Varieties of dates grown.
		Annual.	February to October.		
Maritime subtropical:					
Alexandria.....	68	68.32	70.36	2,049	Aglany, Amri, Bint Aischa, Hayany, Kobi, Samany, Zagloul.
Port Said.....	74	68.95	70.86	2,191	
Gizeh.....	69	67.28	70.86	2,179	
Abbasia.....	62	69.96	73.68	2,714	
Desert subtropical:					
Bedrashen.....					Amhat, Hamrawi, Hayany, Siwah.
Heluan.....	54	68.90	72.54	2,596	
Fayum.....					Saidy, Sultany, Tamr, Hamrawi, Falig, Barakawi, "Bartamoda," Gondeila, "Ibrimi."
Siut (Assiut).....	53	70.29	74.08	3,147	
Dakhleh.....	36	73.92	78.40	3,675	
Aswan.....	39	77.30	81.92	4,296	
Desert tropical:					
Ibrim.....					"Ibrimi," Barakawi, Bartamoda, Gondeila, Kosha, Kulma.
Wadi Halfa.....	34	77.05	81.54	4,160	
Merowe.....	24	81.84	85.61	4,708	
Atbara.....	38	81.73	84.95	4,454	
Khartum.....	33	82.95	85.69	4,396	

THE MARITIME SUBTROPICAL ZONE.

Of the 22 varieties of dates here listed, 7 are grown only in the delta, or their culture extends but a short distance into Upper Egypt. Of these, 5 varieties are used only in the fresh, or "rutab" (succulent), condition. These are the Bint Aischa, Hayany, Kobi, Samany, and Zagloul.

The territory represented by these varieties has the three meteorological stations of Alexandria, Port Said, and Gizeh (Table I), which gives almost uniform mean temperatures, the annual means varying less than 2 degrees and the means for the 9 months of the growth of the flower stalk and fruit, February to October, inclusive, being almost uniformly 70° F.

In explanation of the significance of column 5 of Table I, headed "Heat units above 64.4° F.," the following extracts from pages 63 and 65, Bulletin No. 53 of the Bureau of Plant Industry, by Walter T. Swingle, including table 9, from page 66 of the same bulletin, are here given:

It has been calculated by De Candolle that temperatures down to 18° C. or 64.4° F. have no effect on the flowering or fruiting of the date palm, and a study of the record sheets of a self-recording thermometer kept at Biskra in the midst of a date orchard confirmed the correctness of this assumption. In other words, this relatively high temperature is the zero point for this plant, so far as flowering and fruiting are concerned, though it is able to grow at somewhat lower temperatures. . . . The table [table 9] gives the summation of effective temperatures during the fruiting season of the date palm for a number of points in North Africa and in the Southwestern States.

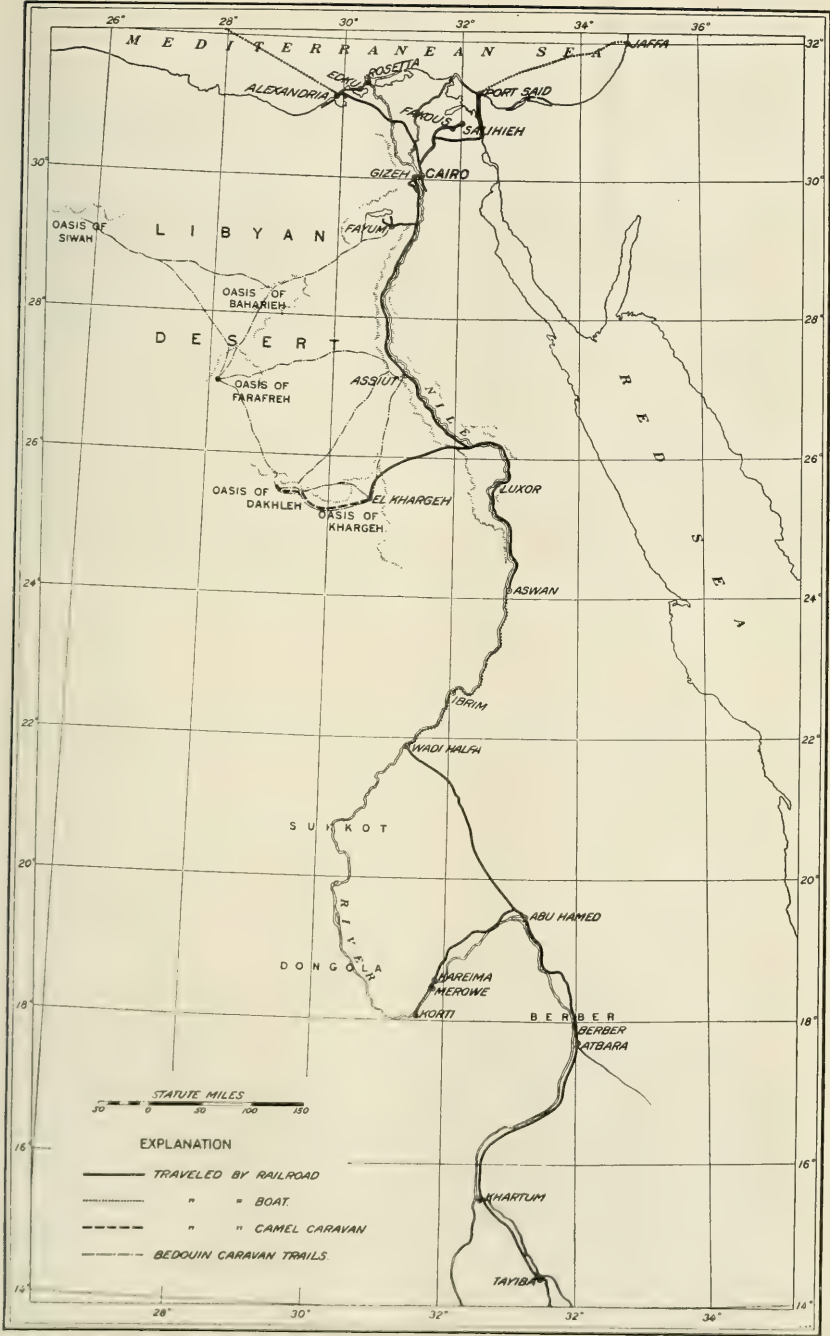
TABLE 9 [Swingle].—*Sum of daily mean temperatures above 18° C. (64.4° F.) for fruiting period of date palm from May 1 to October 31, at the stations named.*

Locality.	Sum of daily mean temperatures above 18° C. (64.4° F.) from May 1 to Oct. 31.		Remarks.
	Degrees centigrade.	Degrees Fahrenheit.	
Algiers, Algeria.....	652	1,174	No dates ripen here.
Orleansville, Algeria.....	788	1,418	Very early sorts mature.
Fresno, Cal.....	1,054	1,897	Average of many years' observations. Dates of sorts grown usually fail to ripen.
Tucson, Ariz.....	1,409	2,538	Average of 6 years' observations. Dates of the sorts now grown usually fail to ripen.
Cairo, Egypt.....	1,593	2,868	Dates ripen regularly.
Phoenix, Ariz. (Salt River Valley).	1,677	3,019	Average of many years' observations. Many sorts of dates ripen regularly.
Biskra, Algeria (Northern Sahara).	1,836	3,304	Average of 10 years' observations. Many sorts of dates ripen regularly; date culture the leading industry. Deglet Noor dates ripen but are not of the best quality.
Ayata, Algeria, 1890 (Oued Rirh region), Sahara.	1,816	3,269	Deglet Noor dates ripened very imperfectly.
Ayata, 1891.....	1,906	3,431	Deglet Noor dates ripened very slowly and imperfectly.
Ayata, 1889.....	2,091	3,764	Deglet Noor dates ripened well.
Tougourt, Algeria (Oued Rirh region).	2,049	3,689	Do.
Bagdad, Mesopotamia.....	2,356	4,242	Average of 5 years' observations. Many excellent varieties ripen.
Indio, Cal. (Salton Basin)....	2,237	4,027	Average of several years' observations.
Indio, 1903.....	2,348	4,227	New thermometers.
Mammoth Tank, Cal. (Salton Basin).	2,585	4,652	Average of 23 years' observations.
Salton, Cal., 1903 (Salton Basin).	2,074	3,734	The coolest summer recorded. Observations taken for the first time with standard Weather Bureau thermometers in the regulation shelters.
Salton, mean.....	2,679	4,823	Average of 12 years' observations.
Salton, 1897.....	3,392	6,106	Hottest summer recorded at Salton.
Salton, 1902.....	2,749	4,948	
Imperial, Cal., 1902 (Salton Basin).	2,106	3,791	

In those calculations 64.4° F. is assumed as the zero point of activity of the date tree as far as flowering and fruiting functions are concerned, any number of degrees of daily mean temperature above that point being available to the tree in forwarding its fruiting functions, though growth of leaves and stem may go on at temperatures considerably lower.

By multiplying the number of degrees above 64.4 in any monthly mean by the number of days of that month the number of available heat units (1 degree 1 day) is arrived at. The summations for the months of May to October, inclusive, in column 5 of Table I have been arranged for comparison with those of the table quoted from Swingle.

The summations of 2,049 heat units for Alexandria and 2,179 units for Gizeh must be fairly representative of the conditions under which the greater number of the date trees of the five varieties mentioned make their growth. (Pl. II.) By comparison with table 9 of Bulletin No. 53, referred to, it will be seen that localities having such low summations are not counted in the possible date-growing territory, except



MAP OF EGYPT AND THE SUDAN, SHOWING THE ROUTE OF TRAVEL AND THE LOCALITIES WHERE DATES WERE STUDIED.



FIG. 1.—A GROVE OF HAYANY DATES ON SANDY, UNIRRIGATED SOIL NEAR RAMLEH,
ON THE MEDITERRANEAN COAST.

Ground water is found at a depth of about 14 or 15 feet.



FIG. 2.—DATES AND VINES NORTH OF THE RAILROAD TRACK, EAST OF RAMLEH,
PLANTED IN DEEP TRENCHES IN THE SAND SO THAT THEIR ROOTS MAY REACH
GROUND WATER.

Note the sand drift in the foreground.

for a few exceptionally early sorts.¹ This apparent discrepancy may be explained for United States localities by the frost interference in the spring and fall, while the Nile delta region is practically frostless; the coast entirely so, while the Gizeh district is subject to rare and only light frosts. With frost immunity in autumn, the dates of the Egyptian maritime belt may hang on the trees, slowly maturing, even after the mean temperature falls below 64.4° F., as it does by the first to the middle of November. It must be remembered, too, that these dates do not mature upon the trees, but are cut and marketed in what is called a "hard ripe" condition, the sugar deposits being probably completed, but with the enzymic actions which promote the ripening not yet begun.

This region, having a mean temperature of 70° F. from February to October, inclusive, does not produce packing dates at all. The Amri, the one important packing date of the delta, is produced at Salihieh, Korain, Fakus, and a few at Birket el Hadji, all points in the margin of the delta lands bordering on areas of bare desert sands. (Pl. III, fig. 1.) Manshia, on the margin of the delta, a few miles north of the Gizeh Pyramids, where considerable quantities of both Amhat and Siwah dates are cured, has a climate so influenced by the proximity of the Libyan Desert that it should be considered under the same category. The record of Abbasia, the suburb of Cairo on the rocky slopes of the naked hills to the northeast of the city, may be taken as most nearly representative of these border localities, especially of Birket el Hadji and Manshia. Here (Table I) the mean for the year is but a fraction below 70°, that for the growing months of February to October being 73.68°; and the summation of heat units from May to October is 2,714. An incomplete record for Ismailia,² on the Suez Canal about 25 and 30 miles southeast of Salihieh and Korain, agrees within an average of 1° in the monthly means with the records of Abbasia and gives an almost identical summation of heat units above 64.4°. The mean relative humidity is between that of Abbasia and that of Heluan, but with less fluctuation than either.

Even with the additional heat afforded by these localities on the desert border, the dates are pulled from the stems in an immature "hard ripe" condition, and the ripening is completed in drying yards, preferably on floors of coarse pebbles to reflect the heat.

It is from such higher temperature conditions at Birket el Hadji, where their groves border the sand hills toward the open Arabian

¹ Thomas H. Kearney, on pages 20 and 21 of Bulletin 92 of the Bureau of Plant Industry, entitled "Date Varieties and Date Culture in Tunis," shows that at Susa on the Mediterranean coast, 120 miles north of Gabes, two varieties of dates are grown where the summation of heat units is probably less than that of Sfax (1,968° F.). These are, however, varieties of inferior quality and the fruit keeps but a short time after gathering.

² Lyons, H. G., *Physiography of the Nile River and Its Basin*, 411 p., 48 pl. Cairo, 1906.

Desert, that the Hayany reaches its earliest maturity, coming to the markets as "Bala Birket el Haggi" (dates of Birket el Hadji) the first of September. It is doubtless with a view to catching this early market that large plantations of the Hayany are being made on the sandy lands in Gizeh Mudirieh, bordering the Libyan Desert above the Great Pyramids.

THE DESERT SUBTROPICAL ZONE.

The next distinctive zone of date culture comprises the narrow Nile Valley of Upper Egypt, from Gizeh to Aswan, and the Libyan oases of Fayum, Siwah, Baharieh, Dakhleh, and Khargeh. For a proper understanding of the conditions, this zone should be considered under three subdistricts: (1) Upper Gizeh, (2) Fayum and the Nile Valley to Aswan, and (3) the western Libyan oases.

SUBDISTRICT OF UPPER GIZEH.

While upper Gizeh includes but a small area, it is decidedly distinctive in the character of the dates grown and the methods of culture and handling. For its temperature records and the number of available heat units we must look rather to the records of Abbasia and Heluan than to those of the Gizeh station.

Proximity to the Arabian Desert on the east and to the Libyan Desert on the west gives to this district, best represented in the vicinity of the railway stations of Bedrashen and Hauamdiyeh, a climate distinctly hotter and drier than that of the delta proper and only prevented from being still more desertlike by the prevailing northerly winds which, blowing from the Mediterranean over the irrigated delta, have only begun parting with their watery vapor and are but slowly acquiring the desert heat. However, a difference of a few degrees in the mean temperature of the growing months, and the accumulation of about 500 more available heat units, enable the growers of this district to produce a packing date equal to the best in Egypt and only awaiting the development of modern, sanitary, and attractive methods of handling to take its place with the Deglet Noor and Fard dates, which are imported to supply the high-class trade in Cairo. The Siwah is the important variety of this section, though considerable quantities of the Amhat are also packed. (Pl. III, fig. 2.) Detailed descriptions of the Siwah and the discussion of the problem of its relation to the Saidy of the oases will be found in the following pages.

The points of greatest economic importance to Egypt are, first, that this valuable variety, the Siwah, could be grown as well or even better on up the valley past Wasta and to the great date-growing section about Assiut and in the Fayum, where it is only beginning to be planted. It could very profitably replace thousands of balady, or seedling, trees of those districts, the low-grade fruit of which is scarcely more valuable than the leaf products.

The second economic point is that to get the real profit the present careless and filthy methods of curing and packing must give way to modern sanitary methods, and the fruit, in itself really of high quality, must be packed in neat, attractive boxes or cartons, when it would command three times the retail price it brings to-day.

SUBDISTRICT OF FAYUM AND THE NILE VALLEY.

The valley portion of the desert subtropical zone, beginning above Gizeh and extending, for convenience, to the first cataract, at Aswan, comprises the provinces of Beni Suef, Minieh, Siut (Assiut), Girgeh, Kenh, and Aswan, with a total of over 3,000,000 taxed date trees, or more than half of the entire number of the taxed trees of Egypt. While a few of the choicer named varieties are grown in gardens of well-to-do people, nearly the entire number of these trees are of the balady, or seedling type, of every color and character, though those of superior quality are few, and there is a strong leaning toward the dry types. It is doubtful whether anywhere else in the world can be found so large a number of date trees of so low a commercial quality and containing so small a number of trees of standard varieties and uniform product. The nearly a half million date trees of Fayum are of about the same character, and from the similarity of the climate to that of the northern portion of Upper Egypt Fayum is included with the valley division of the desert subtropical zone.

If one but for a moment considers the possible difference between financial returns which would be realized from these millions of balady, or seedling, trees and an equal number of such valuable varieties as might be grown in their places, the results are astounding. Sir William Willcocks's estimate of the annual value of the product of 5,200,000 date trees of Upper Egypt at £1,040,000 makes the average value of each tree only 4 shillings, or about \$1. Remembering that this portion of the Nile Valley and the depression of the Fayum afford ideal conditions for growing the choicest of the world's date varieties, we should picture these sections as planted with such choice Egyptian varieties as the Siwah, the oasis Saidy, the Algerian Deglet Noor (which would find its optimum temperature conditions about Kenh or Luxor), and some of the most valuable Arabian varieties.

From the most reliable estimates that could be obtained at Bed-rashen, the annual revenue realized by the grower of the Siwah variety would be about \$2.50 per tree, even with the present crude methods of handling. The Saidy, apparently adapted to the higher heat conditions of the upper valley, would be no less profitable. With modern packing methods the above figures could at least be doubled. If the quality of the trees of this section could be so changed that they would be bringing an annual return of £1 per

tree instead of one-fifth of that sum, over £4,000,000 would be added to the income of these people. This £4,000,000 a year added to the value of the date crop of this narrow stretch of valley of about 500 miles in length would vastly change the economic conditions of Upper Egypt. Of course, it would require years to bring about such a change, to convince the native cultivators of the desirability of such a change being the most difficult part of the problem. To develop the market for the higher-priced product would also require time. All of this suggests that the excellent work on dates already begun by the horticultural division of the Egyptian Department of Agriculture might profitably be very greatly expanded.

In the upper end of the valley division the mean temperature rises almost to that of the desert tropical, and the air is of a desert dryness. Here it is not surprising that we find considerable numbers of the date varieties from Nubia, the Sukkot country, and Dongola. What may be considered their fancy varieties, the "Bartamoda," Gondeila, and Kulma, are represented by only a few trees, to be sure, but the valuable dry date, Barakawi of Dongola (here called "Ibrimi") is a good deal planted, and apparently any seedling with a close resemblance to it is admitted into the family.

SUBDISTRICT OF THE LIBYAN OASES.

The Libyan oases have a date industry related throughout the series by the culture of one valuable packing variety, the Saidy. (Pl. IV, fig. 1.) A number of other varieties, as the Frihy, Gazaly, Kaiby, and Wedi, seem to be common to Siwah and Baharieh, but are not known in Dakhleh and Khargeh. But the great export date of all these oases is the Saidy. Whether, as the name suggests, this was originally from that part of Upper Egypt known as "Es Siyd" is wholly a matter of conjecture. The fact that it is scarcely at all known there now would make this explanation doubtful.

No data are available concerning the oasis of Siwah, either as to weather conditions or the number of date trees. The only meteorological records for these oases are those kept at Mut,¹ the capital of Dakhleh, which are given in the annual report of the Ministry of Finance for the years 1905 to 1911, inclusive. The data here would be fairly representative for Khargeh, but doubtless a few degrees too warm for Baharieh and Siwah. Table I shows that the mean annual temperature for Dakhleh is a little above a mean between Siut (Assiut) and Aswan, while the dryness of the air is greater than at Aswan and next to that of Wadi Halfa. The available heat units above 64.4° F. reach 3,675, which is very close to the optimum for the Deglet Noor at Tuggurt (Tougourt), in Algeria (quoted table 9,

¹ Pronounced "moot."

p. 8), where that variety is at its best, though probably the air at Dakhleh is much drier.

This comparison throws light on the heat requirements of the offshoots of the Saidy, which we are now importing, and suggests that the Coachella and Imperial Valleys of California will probably prove best adapted to its culture. As seen by the writer at Khargeh and Dakhleh, and after arrival at Fayum by camel from Baharieh, these dates are packed in solid masses in flattened baskets of braided date-leaf pinnæ, holding 80 or 160 rotls each; that is, either four or two of them make an ardeb weight of about 320 pounds, the usual camel load. At Dakhleh the usual price is about 50 piasters, or \$2.50, for an ardeb, but in years of crop shortage the price advances sometimes to 70 piasters, or about \$3.50 per ardeb, even this being but a fraction over a cent a pound. The best information available shows that they bring wholesale about $3\frac{1}{2}$ cents a pound in the valley and retail in the stalls at 1 piaster per rotl, or about 5 cents a pound.

The Corporation of Western Egypt, an English syndicate which formerly operated a series of trading stores in Dakhleh, tried the experiment of packing these dates in attractive cartons for the English market, but, while they found a ready sale, the extra cost of camel transportation to the railroad necessitated by the improved pack, left very little margin for profit. With rail and steamer transportation at the door, so to speak, in Nile Valley towns, this excellent oasis variety ought to be a very profitable one to plant in the portions of Upper Egypt having temperatures most nearly corresponding with the oases, probably Girgeh and Kenh Provinces, which are now taxed on 1,250,000 unprofitable balady trees.

THE DESERT TROPICAL ZONE.

The desert tropical zone is marked by a decided increase in temperature over the lower portion of the Nile Valley and a lowering of the relative humidity to below even that of Dakhleh, in the heart of the Libyan Desert. Perhaps, owing to local conditions at the observing station, the weather records for Aswan (lat. N. $24^{\circ} 2' 25''$) show higher monthly means for July, August, and September than Wadi Halfa (fig. 2), just within the Tropics (lat. $21^{\circ} 54' 49''$). These temperatures would doubtless be too high for the upper portion of the desert subtropical zone from Luxor to Aswan, where the date culture of this zone practically ends, on account of the submergence of the narrow valley lands by the Aswan reservoir.

There is a decided step in temperature conditions between this region and the northern portion of the desert tropical zone represented by Ibrim. Scattered groves of dates appear shortly south of the Tropic of Cancer, but the heaviest culture begins about Korosko

and is at its best in Egyptian territory from there through the Ibrim district, the dry variety called "Ibrimi," from this locality, giving character to the output. These dates were in considerable repute 100 years ago, when Burekhardt passed through the valley, though later he compares them unfavorably with those of Sukkot. Burekhardt's observations on the dates of the districts he visited confirm in a very interesting way the information which was gleaned by the writer while in the Sudan about the spread of the date industry.¹ Burekhardt speaks in high terms of the dates of Sukkot and says that they are brought by the Arabs from Merowe and taken by camel caravans across the desert to that point, Dongola having but few dates, and those of poor quality. At Berber, the year following, he mentions dates as a great luxury which had to be bought from the Dongola traders. He also mentions as a landmark a single tall date tree near Shendi, the only one of its kind in that region. These statements agree perfectly with those made by the chief men of Merowe and vicinity that a hundred years ago Dongola had no dates, all of their four commercial varieties having been obtained from Sukkot.

The prevailing dry character of the dates of this zone was anticipated in the dry dates of the upper portion of the last zone from Keneh to Aswan, but is now fully in evidence. The contrast between the date output of this zone and that of the maritime subtropical zone is striking. Of the dates of the delta region, not one is a dry variety. As previously stated, only one or two are fair packing sorts. The tendency is strongly to the "rutab" or crisp (succulent) sorts, too low in sugar content to be self-preserving as they ripen. A few specimen trees of the dry types seen in the delta region were plainly not adapted to the local conditions, and the fruit matured was poor in quality.

The development of a good dry date is, beyond doubt, a matter of climatic conditions, of heat and low humidity combined. It is true that very soft, sirupy dates of the type of the Hamrawi may develop under as hot and dry conditions as those at Dakhleh and Khargeh, but their sugar content is very much higher than for similar dates in the cooler and highly humid delta. The Dongola region of highest mean temperature of any successful date region of Africa, and also of lowest relative humidity, does not produce one date variety of a clearly soft, sirupy type. Its nearest approaches, Kulma and Bentamoda, are to be classed as semidry dates. Their leading date, the Barakawi, is commended by those people because they say it is so hard that the weevils can not hurt it, and that it will keep for two years. (Pl. IV, fig. 2.)

¹ Burekhardt, J. L. *Travels in Nubia*. Ed. 2, 498 p., illus., 2 maps. London, 1822.

Algerian Deglet Noor trees from offshoots brought to Merowe were shown to the writer by Gov. Jackson in first fruit, and in the latter part of September the fruits were ripe and as hard as the dry dates of the country. This same tendency to become dry or "mummified" is observed in the Deglet Noor in the Coachella Valley in California in exceptionally dry, hot seasons, especially if a minimum amount of water is given them.

The preponderance of dry dates in the Nubia and Sudan portions of the Nile Valley may, then, be attributed to two general causes, namely, the general tendency of the climate to the production of dry varieties and the selection of such dry varieties as are of greatest commercial value. Such selection is on account of the readiness with which they are cured and the convenience with which they are stored and transported, their indestructible character permitting their being packed in stout bags and carried by camel caravans subject to the hardest conditions, yet always ready as an article of food without preparation.

Referring to the temperature diagrams in figure 1 and the plotted curves in figure 2, it will be seen that at Merowe and Khartum the lowest monthly means, December and January, are considerably above the line of 64.4° F., assumed to be the zero point of activity of the date tree in flowering and fruiting functions. In spite, however, of the high December and January means, the date trees of Dongola flower and are pollinated at about the usual time of dates farther north. According to Davie, "pollination takes place in February and March," practically the same months when it is practiced in Dakhleh and Khargeh, where the means of December and January are considerably below 64.4° F. That is, a continuous mean temperature for those months of several degrees above the assumed zero point does not prevent these trees from having a resting period and postponing the flowering period to about the season when it occurs in considerably cooler localities. Davie records that the fruit at Merowe ripens about seven months after pollination, or September and October, but at the time of the writer's visit to Merowe, on September 20, nearly all the dates had been gathered, the Barakawi harvest had ended practically a week previously, and much of the fruit was being marketed. These facts point strongly to the necessity of a study of date-tree activities from another standpoint than that of a mean temperature of 64.4° F. as the zero point.¹

¹ Dr. A. E. Vinson, of the Arizona Agricultural Experiment Station (in *Botanical Gazette*, vol. 37, p. 321-327), describes the rate of leaf growth of two trees each of the Deglet Noor and Rhars varieties at the cooperative date garden, Tempe, Ariz., through the growing seasons of 1903 and 1907 and calls attention to the agreement of the rate of growth with the mean minimum rather than with the mean maximum temperatures of the period studied. His diagrams are, however, too much involved with the waning growth of the successive leaves as they approach maturity to make his conclusions convincing. In fact, his growth curves show a more intimate coordination with the surface-soil temperature than with any other factor.

The early maturity of all the Sudan varieties is an indication of a somewhat definite number of available heat units required to mature the crop, the high temperatures of the early part of the growing season hurrying them along more rapidly than, for example, those of Khargeh and Dakhleh. The summation of 4,708 heat units above 64.4° F. shown at Merowe for the months of May to October, inclusive, to be reduced to what the date crop has actually required should have subtracted from it the summation above 64.4° F. of the month of October and half of September, or 1,096 units, leaving 3,612. Something should be added, however, for the excessive heat of Dongola in March and April over stations farther north.

If we regard the Dongola season as beginning 6 weeks earlier, through the more rapid push of the last half of March and the month of April, we can get a 6-months' summation of heat units at the time the trees actually use them, which will be a fairer index of the crop requirements than that in Table I. For this purpose Table II has been prepared.

TABLE II.—*Mean monthly temperatures and summation of heat units above 64.4° F. for the growing period of the date at Merowe, Dongola Province, from March 15 to September 15.*

Month and days.	Mean.	Above 64.4° F.	Days.	Summation.
	° F.	° F.		
Mar. 15-31.....	76.82	12.42	15.5	192.51
Apr. 1-30.....	85.46	21.06	30	631.80
May 1-31.....	89.87	27.47	31	789.57
June 1-30.....	92.21	27.81	30	834.30
July 1-31.....	90.23	25.83	31	800.73
Aug. 1-31.....	89.33	24.93	31	772.83
Sept. 1-15.....	91.49	27.09	15	406.35
Mean, 7 months.....	87.77			
Total, 6 months (middle of March to middle of September).....				4,428.09

This calculation of the summation reduces the heat units used by about 300, but still shows that the Dongola dates are produced under higher heat conditions, as well as lower humidity conditions, than any date crop of which we have record.

A review of Tables I and II shows clearly the necessity of estimating the time-heat requirements of the dates of different varieties, not arbitrarily from May to October, inclusive, as was the best that could be done with the imperfect information at hand when such studies were begun, but from some definite period in the history of the development of each variety, as exemplified by individual trees in typical localities. Atmospheric moisture, soil character, and soil moisture will be important factors to be taken into account. Probably the date of pollination is as definite a time as could be selected at which to begin the estimate of heat requirements.



FIG. 1.—A PLANTATION OF AMRI DATES NEAR THE VILLAGE OF BIRKET EL HADJI, PROPERTY OF THE OMDA OF THE VILLAGE.



FIG. 2.—DATE TREES OF AMHAT AND SIWAH VARIETIES ALTERNATING WITH CORN FIELDS IN THE RICH NILE BOTTOM LANDS NEAR BEDRASHEN, IN GIZEH PROVINCE.



FIG. 1.—A DATE GROVE, CHIEFLY OF THE SAÏDY VARIETY, NEAR THE VILLAGE OF RASHIDA IN THE DAKHLEH OASIS.

The giant tree in the center is a male.



FIG. 2.—DATE TREES, CHIEFLY BARAKAWI, ALONG THE NILE IN DONGOLA PROVINCE, BELOW MEROWE, SHOWING "MOTHER AND DAUGHTER" SYSTEM OF GROWTH.

Note the sakieh used for irrigation.

DESCRIPTION OF VARIETIES.

AGLANY.

Trees of the Aglany variety are tall and have slender trunks and leaves 10 to 12 feet long, with a graceful curve at the apex. The leaf bases are 7 to 9 inches broad and about 2 inches thick, diminishing gradually to the normal size of the rib, which has a regular taper to the rather slender apex. The dorsal surface of the rib is moderately rounded, while the ventral surface presents a sharply angled ridge. The spine area is about 20 per cent of the blade length; the spines are rather heavy, tapering to a slender acute apex, 2.5 to 9 inches or even 12 inches long, passing to a thick ribbon pinna 18 to 26 inches long. The normal pinnæ at 3 to 6 feet from the base of the blade are 22 to 27 inches long and three-fourths or seven-eighths of an inch to $1\frac{1}{8}$ inches broad. From the middle of the blade they gradually diminish in length, but are still 18 to 21 inches long at 10 feet from the base and 13 to 16 inches long at the apex. Their greatest breadth, $1\frac{1}{4}$ to $1\frac{3}{8}$ inches, is at from 6 to 10 feet from the base. The pulvini are heavy, those on the spine and lower pinnæ being very heavy, but only slightly caudate, and there are no coalescent groups of pinnæ. The thickness of the pinnæ blades is about 0.017 to 0.018 of an inch.

The antrorse pinnæ form about 25 per cent of the whole number on the blade, the introrse and retrorse about 35 per cent each, the others being undetermined. The paired groups of pinnæ form more than half of the entire number, the triple groups rank next, and there are a few quadruple groups.

The divergence of the pinnæ from the rachis is rather slight, about 15° to 20° for the antrorse and 25° to 30° for the introrse and retrorse classes. They lie close to the blade plane, the outer half of the blade being broad, smooth, and nearly flat.

The fruit¹ is $1\frac{1}{8}$ to $1\frac{1}{4}$ inches long, three-quarters of an inch in diameter, narrowly elliptical in outline; color, lemon yellow, curing to a dull brown. The skin is thin, the flesh three-sixteenths to one-quarter of an inch thick. These dates, when fully ripe, are very sweet and sirupy, but rich enough in sugar to enable them to be dried and packed for shipment though they are largely eaten fresh. The seeds are 1 inch long, five-sixteenths of an inch broad, rather oblong, with broadly rounded ends. The ventral furrow is deep, the germ pore being nearly central. At Salihieh, where this variety is chiefly grown, it is ripe about the first week of November.

AMHAT.

(Notes taken at Bedrashen and Abu Nemrus.)

Trees of the Amhat variety are tall (Pl. III, fig. 2) and have medium-heavy trunks and glaucous blue leaves $10\frac{1}{2}$ to $13\frac{1}{2}$ feet long, with bases of moderate width and the rather stout ribs strongly rounded dorsally and decidedly arched ventrally, giving unusual approach to a cylindrical cross section.² The spine area is $2\frac{1}{2}$ to $4\frac{1}{2}$ feet, the medium-heavy spines from 2 or 3 inches long below to 8 or 9 inches in the upper ones and passing to stout spike pinnæ 23 to 27 inches long. The succeeding normal pinnæ are 24 to 27 inches long, decreasing but slightly till near the apex, where they drop to 20, 17, and finally 14 inches.

The pinnæ range in width from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches, only a few of the apical ones dropping to five-eighths or three-fourths of an inch broad, and they are rather firm and stiff

¹ For the characters of the ripe fruit the writer is indebted to Mr. Thomas W. Brown, horticulturist of the Egyptian Ministry of Agriculture.

² For the system of technical descriptions used in the following pages see "Botanical Characters of the Leaves of the Date Palm Used in Distinguishing Cultivated Varieties," Bulletin 223, United States Department of Agriculture, by the writer of this bulletin.

throughout, with a thickness of 0.017 to 0.020 of an inch. The pulvini are from medium to heavy, a few being slenderly caudate and coalescent.

The diversity of the angles of the pinnæ gives a rather ragged appearance to the blade, and the position of the antrorse class keeps the valley of the blade rather narrow clear to the apex, a somewhat unusual feature. The analysis shows unusually low numbers of introrse pinnæ and a corresponding high proportion of the paired antrorse-retrorse groups.

The fruit stalks are of medium weight, about 36 to 40 inches to the fruiting head, which is 12 to 15 inches. The strands, or "shamrokh," 18 to 22 inches long, are set with fruit on the outer three-fifths of their length.

The oval fruits are $1\frac{1}{8}$ to $1\frac{1}{4}$ inches long and about three-fourths of an inch broad, the broadest portion being a little beyond the middle.

The color is orange yellow, curing to a brownish black, the packed color being an oily black for which there is no equivalent in the color scheme. The skin is thin and the flesh sticky and of a color difficult to place in the scale, a "maroon purple" (R. XXVI)¹ much deepened being the nearest equivalent. The flavor is rich and very sweet, but rather cloying.

The seeds are about three-fourths of an inch long, five-sixteenths of an inch broad, nearly oblong, with rounded ends, the apex obtusely pointed. They are nearly cylindrical, smooth dorsally, the germ pore placed a little nearer the apex, the ventral surface somewhat corrugated, the ventral furrow narrow and shallow. Their color is very close to "auburn" (R. II).

This variety is gathered before it is fully ripe and dried somewhat in the sun, spread on palm leaves in drying yards. The dates are then tramped into huge baskets of braided date leaves, holding from an ardeb of 320 pounds to 600 or even 752 pounds. While this is a date of rather valuable qualities, certainly much superior to the Amri in flavor, it is handled in such a careless and filthy manner, which filthiness is enhanced by the stickiness of the fruit, that the whole product is a dirty, sticky mass that finds a sale among the poorer people at prices considerably below those commanded for the Siwah of the same district.

The chief area of the production of this variety is in Gizeh Province, in the districts around Bedrashen, Hauamdiyah, and Abu Nemrus. There is also a considerable planting about Manshia, north of the Gizeh Pyramids.

AMRI.

(Notes taken at Salihieh and Birket el Hadji.)

Trees of the Amri variety² (Pl. III, fig. 1) have unusually airy and feathery tops, an appearance due both to the slender, flexible rib and to the narrow pinnæ.

The leaves are 11 to 12 feet long, the rib light throughout, narrow and strongly rounded at the base and tapering to a slender apex, which becomes very thin laterally. The light ribs are counted of small value in the manufacture of crates and other material of that character.

The spine area is only about 15 inches, the spines from 2 to 6 or 7 inches long, slender and acute. They pass into soft ribbon pinnæ varying from 10 to 16 or 18 inches in length. The normal pinnæ become 22 to 23 inches long at 4 or 5 feet from the base and gradually diminish to 10 or 12 inches at the apex.

Through the middle of the blade the pinnæ reach a breadth of only seven-eighths of an inch or 1 inch, while the upper and lower ones are from one-half to three-fourths of an inch broad. Several of the lower pinnæ are somewhat "necked," as is common in Hayany, and the apical pinnæ are noticeably winged.

¹ The color references in this and the following descriptions are from Ridgway's "Color Standards and Nomenclature," Washington, D. C., 1912. Published by the author. The color cited, "maroon purple," is quoted from Ridgway's plate 26, being indicated by "R. XXVI."

The ripe fruits are 2 to 2½ inches long, 1 inch to 1¼ inches broad, nearly oblong (fig. 3), sometimes a little the broadest at slightly above the middle, rounding to a blunt and often oblique apex, with a short awnlike point. The color is "liver brown" (R. XIV) or "Hessian brown" (R. XIII), the skin thick, often loose from the flesh and thrown in coarse wrinkles. The flesh is three-eighths to five-eighths of an inch thick, coarse fibrous, with some stickiness, and with a zone of tough "rag" one-sixteenth of an inch thick next to the seed.

The seeds are large and often rough and corrugated, 1¼ to 1½ inches long, three-eighths of an inch broad, often poorly filled out at the base; the germ pore placed rather toward the base, the ventral furrow broad and shallow. The color of the seed is as near "Mars brown" (R. XV) as can be selected.

At the time of the writer's visit to Salihieh, November 8, the bulk of this crop had gone out, so the date of ripening may be set at about November 1.

This date has considerable sweetness, but the flavor is coarse and common. Its large size and fine appearance, along with its good packing qualities, can alone account for the popularity of the variety.

The production of the Amri is brought to the greatest perfection in the regions of Korain and Salihieh, on the sandy borderland between the delta and the desert; and is grown in small numbers under similar conditions about Merg and Birket el Hadji, which seems to be about its southern range. It probably ranks as the most important export variety of Egypt, though data in this regard are very meager. The best packs seen by the writer were in the regions above mentioned, where the pebble-floored drying yards secured some degree of cleanliness, and where the reflected heat insured a more nearly perfect curing of the dates than is obtained under other conditions.

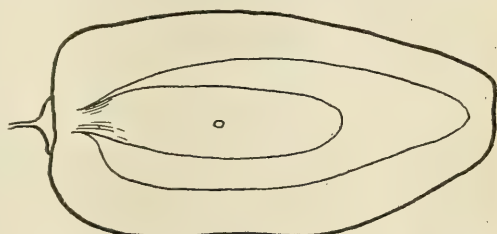


FIG. 3.—Outlines of the Amri date from the omda's garden, Salihieh, Lower Egypt. (Natural size.)

In the gardens of this section the dates are packed in boxes of light pine boards, which are cut and put together in small factories in the villages. These boxes were not exactly uniform in size, but hold from 40 to 50 pounds each, according to how closely they are packed. The most that could be learned about the market was that the bulk of the crop is shipped from Alexandria to points in southern Europe. This date is found rather rarely in the market stalls of Cairo.

BARAKAWI.¹

(Sukkoti, Ibrimi, Ibrihimi.²)

The leaves of the Barakawi variety are 9 to 10 feet long, with a graceful feathery taper. The spine area is 18 to 24 inches, the spines slender and acute, the lower ones weak and short, but the higher ones become 2½ to 4 inches long, passing into ribbon

¹ The original name of this variety, as obtained from Sukkot by the Dongola people, is undoubtedly Barakawi, which in the Arabic of that province signifies "blessed," as ascertained by Mr. Thomas W. Brown, of Gizeh. Some of the chief men of the province, however, write the name in a form which must be transliterated "Birkawi," adjective for the noun "birka," a pond or pool. Originating in Sukkot, offshoots of the variety were carried down the river to below Wadi Halfa, where they were given the name Sukkoti. After a shipping trade in these dates from the Ibrim region below Halfa was carried on to points down the river, they took the name Ibrimi, and now the Barakawi dates going to Cairo from Dongola Province are sold under the name Ibrimi.

² Poppehor, in "Date Growing in the Old and New World," gives this variety as "Ibrihimi, vulgarly Ibrimi, Abraham's date," being evidently unacquainted with the geographic origin of the name Ibrimi.

pinnae 10 to 15 inches long, only three-eighths to one-half an inch broad, soft, thin, and acute.

The normal pinnae are 12 to 16 inches long, three-fourths of an inch to 1 inch broad, but the blade tapers with a feathery grace toward the apex where the pinnae are but 6 to 9 inches long and one-half to five-eighths of an inch wide. The pinnae are very smooth in their arrangement, falling nearly into two ranks, with a divergence from the plane of only 10° to 30° , and from the axis of 30° to 45° . The groups fall into twos, threes, and fours, but the difference in the angles formed by the antrorse, introrse, and retrorse pinnae is not very pronounced, and toward the apex many of the pinnae are difficult to place.

The pulvini are inconspicuous and none caudate.

The fruits are of the dry type, 2 to $2\frac{1}{4}$ inches long, three-fourths of an inch broad at the base, tapering acuminate to a small obtuse apex. They are usually oblique and unsymmetrical, often slightly curved (Pl. V). The surface is broken by fine, branching, longitudinal furrows, but is more nearly smooth toward the base. The color of the apical half or two-thirds is "chestnut brown" (R. XIV) or in some cases more nearly "bay" (R. II). There is a faint lavender bloom. The basal portion of the fruit is usually a shade between "honey yellow" and "Isabella color" (R. XXX).

The firm dry flesh is three-sixteenths of an inch thick, having an outer zone sometimes the color of the exterior, the inner portion being pale "cream color" (R. XVI) or "cartridge buff" (R. XXX). The flavor is moderately sweet, wheaty, with a suggestion of a fruity acid, and no hint of astringency. With those who are fond of the appetizing flavor of the best dry dates without the cloying richness of the sirupy type, this will find a place among the three or four best varieties. The seeds are small for the size of the fruit, about $1\frac{1}{8}$ inches long, one-fourth to five-sixteenths of an inch broad, nearly oblong, smooth, with a broadly rounded apex. The small germ pore is placed at about three-fifths of the seed length from the base, the ventral furrow being narrow but rather deep. In color they are "snuff brown" (R. XXIX) in the darker parts, fading toward "cream buff" (R. XXX) in the lighter portions.

This is the great commercial date of the Dongola Province, and it is claimed, as for the three other varieties, that it was brought from the Sukkot country many years ago, a claim fully sustained by Burckhardt's account.

The fruit is reputed to possess the best keeping qualities of any variety known in Nubia or the Sudan. The natives say that it will keep for two years, and that it is so hard that the weevils do not get into it. It is in great demand among the nomads, who come in from as far as Kordofan to purchase these dates at the Dongola market towns. The price as given by Davie¹ is 72 to 96 piasters per ardeb of 320 pounds, equivalent to \$1.12 $\frac{1}{2}$ to \$1.50 per 100 pounds.

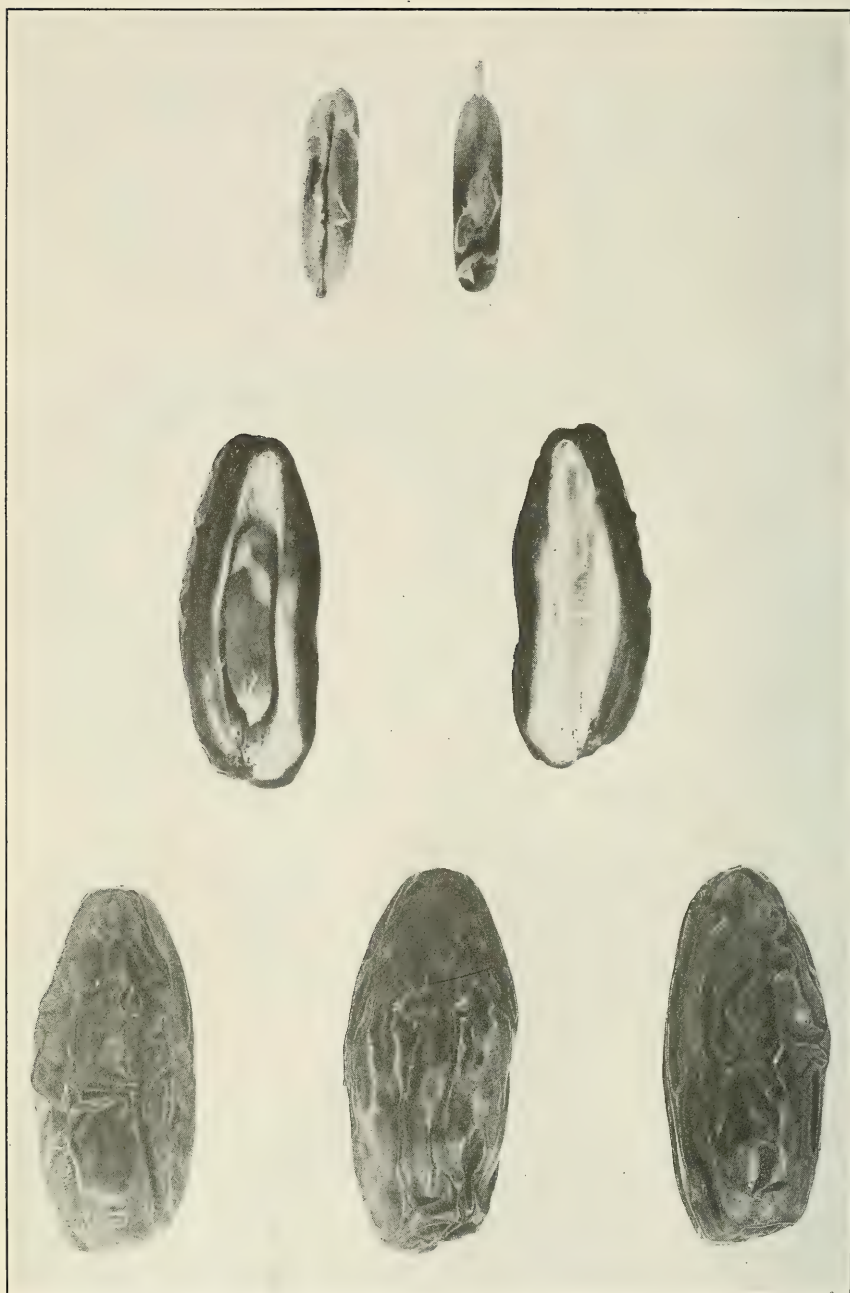
Col. H. W. Jackson, Governor of Dongola Province, states that about one-third of the output of this date now goes to Egypt; also that they are much sought after by the pilgrims to Mecca, their fine keeping and transporting qualities, as well as their excellence as a food, making them very desirable for such a long journey. One of the prominent sheiks told the writer that these dates are sold in Egypt under the name Ibrimi.

The region of the chief production of this date is the great bend of the Nile, a stretch of about 150 miles lying between the third and fourth cataracts. For the greater part the bottoms are very narrow, scarcely more than garden patches, and often the rugged sandstone bluffs, crowned with the ruins of ancient Roman fortresses or the more recent native retreats in time of river raids, rise abruptly from the river bank. There are no irrigation canals in the entire province, and with the exception of some small flood areas and the infiltration received by trees near the river banks, the date trees are all irrigated by means of rude geared wheels of acacia wood (sakieh) turned by

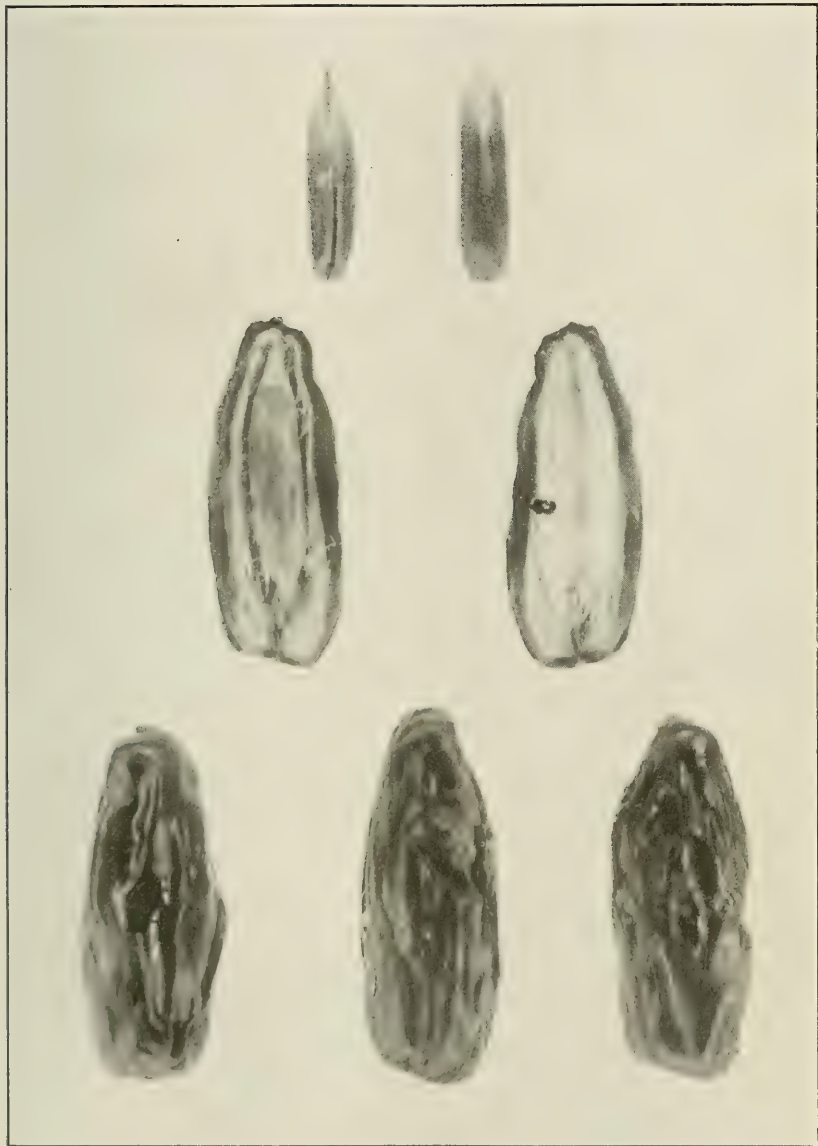
¹ Unpublished manuscript, "The Date Palm," by W. A. Davie, Inspector of Agriculture, Khartum, May, 1911; courtesy of the Director of Agriculture and Forestry, Sudan Government.



SAMPLES OF THE BARAKAWI DATE, THE CHIEF COMMERCIAL VARIETY OF THE SUDAN; FROM MEROWE, BUT KNOWN AS IBERIMI IN THE EGYPTIAN MARKETS. (NATURAL SIZE.)



SAMPLES OF BENTAMODA, THE CHOICEST VARIETY OF SUKKOT AND DONGOLA DATES,
FROM MEROWE. (NATURAL SIZE.)



SAMPLES OF BARTAMODA DATES FROM ASWAN, WHERE BUT FEW TREES ARE KNOWN;
THE SAME FRUIT AS BENTAMODA. (NATURAL SIZE.)



SAMPLES OF CORRAGIA, A MINOR VARIETY OF DATE FROM MEROWE, SUDAN. (NATURAL SIZE.)

bullocks, which lift the water by means of an endless chain of earthen jars set on heavy ropes. (Pl. IV, fig. 2.) Where the lands are the best and the culture the most intensive the sakiehs are often not more than 100 feet apart, and the moaning creak of a score of these along the river bank on a hot tropical night is one of the memories that will abide longest with the visitor to Dongola.

Except in the newest plantations, there is little regularity in the setting of these date trees and the practice of allowing from three to seven or eight "daughter" trees, offshoots from the "mother" tree, to grow up around it, inclined at various angles from the perpendicular, gives to these Dongola date plantations a weird and tropical picturesqueness, which contrasts strongly with the straight-bodied, formal appearance of the groves seen about Merg or Bedrashen.

Either there is an appreciation of the fact that in this region of dry air and intense heat a greater insulation of the growing center is needed, or perhaps the temptation to remove leaf material to sell is not so great; at any rate, the tops of the Dongola date trees are left much heavier than in Lower Egypt, and the leaves are not cut so closely at the base.

The Dongola people are apparently very well satisfied with their Barakawi industry and are offering no offshoots for sale, but are planting new groves as fast as they can get the material.

The writer was informed that there is also a considerable production of this variety, under the name "Ibrimi," in Berber Province, which is the uppermost date-producing region of the Nile Valley, including the fourth and fifth cataracts; for while there are many date trees about Khartum, the fruit is hardly produced in commercial quantities.

In the reaches of the Nile Valley, between Wady Halfa and Korosko, there are narrow stretches of alluvial land and islands which, together, permit the cultivation of many thousands of date trees, of which this variety, under the name "Ibrimi," is the chief. An important section of the valley is on some maps designated as Wady Ibrim, to which an ancient ruin known as the Kasr Ibrim doubtless gave the name, and which is now represented by a modern native village of the usual squalid type. The product of this section reaches the markets of Lower Egypt under the name "Ibrimi" and leads to the inclusion of the Barakawi dates from Dongola under the same name. As there is a great variation in size and appearance among the dates marketed as "Ibrimi" in Cairo, there is good ground for the suspicion that the crop from a good many seedling trees bearing fruit closely resembling the original variety is marketed under that name.

BENTAMODA.

(Betamoda, Bartamoda.)

Trees of the Bentamoda variety have moderately heavy trunks and gracefully curved leaves 9 to 12 feet long, with light, slender ribs and narrow bases. The spine area is very short, the slender needlelike spines being from 1 inch long below to 5 or 6 inches long where they pass to the narrow, grassy ribbon pinnae. The normal pinnae range in length from 12 or 16 inches to 18 or rarely 21 inches at a little beyond the middle of the blade, holding 12 to 16 inches to near the apex, where they shorten abruptly to a range of 7 to 10 inches.

The pinnae are narrow throughout, seven-eighths of an inch to 1 inch broad, rarely exceeding $1\frac{1}{4}$ or $1\frac{1}{2}$ inches in the wider ones. Their texture is soft and grasslike, with a thickness of 0.011 to 0.014 of an inch. The pulvini are light, in some cases slightly caudate, but with no groups coalescent. At the base of the blade the pinnae have a light axial divergence and a strong divergence from the blade plane, forming a narrow, close valley, which opens out toward the middle of the blade, where the pinnae are at about 27° to 30° from the blade plane, giving a rather smooth uniform leaf toward the apex. The general color is rather light green with a thin waxy bloom.

The fruit in ripening presents a very beautiful appearance, the bunches being heavy on long strands (shamrokh). The half-ripe fruit is about $2\frac{1}{4}$ inches long, often oblique, a little curved, and with a peculiar long-pointed apex (Pl. VI). The color is a mingling of "apricot orange" (R. XIV) with "ochraceous orange" (R. XV). The flesh is thick, the interior of which is satiny white. In ripening, the fruit becomes considerably reduced in size, and is about 2 inches long and seven-eighths of an inch to 1 inch broad, with the skin softly wrinkled and an appearance of bloom. The color is now a shiny "Brussels brown" (R. III). The oblique form and long point are still well retained (fig. 4). The flesh is soft, but not sticky, very rich and sweet, with a distinctive flavor, which places it in a high class among dates. The smooth oblong seed is narrow and rather delicate for the size of the fruit, being $1\frac{1}{4}$ to $1\frac{5}{16}$ inches long, five-sixteenths of an inch broad, rounding about equally and obtusely at either end, but the apex is often apiculate. The germ pore is placed about two-fifths of the seed length from the apex, the ventral furrow being shallow and narrow. The color of the seed is close to "Sayal brown" (R. XXIX).

Samples of this fruit brought from Merowe and examined in Washington on May 20 of the following year, though still in perfect condition, did not possess quite the high flavor of the recently matured fruit.

This variety is considered by the English residents of the Dongola and Halfa provinces to be the finest date of dessert quality in the Sudan. It is nowhere found in

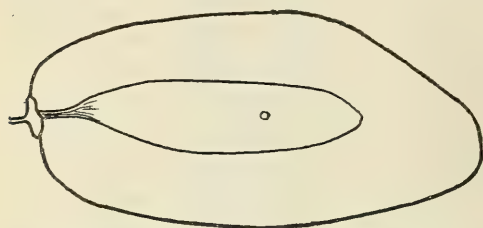


FIG. 4.—Outlines of the Bentamoda date in fresh condition, from Merowe, Dongola Province, Sudan. (Natural size.)

commercial quantities, and the possession of a few trees is regarded as rather a mark of wealth and distinction, the fruit being kept to offer to guests or sent as presents. The gift of an offshoot from this variety is a mark of especial favor or courtesy. Davie states that this variety "can be treated as a soft or a dry date," also that "an ardeb (300 to 320 pounds) will fetch as much as 192 piasters (\$9.62 in United States

money). There is not much trade in this variety, however, as the quantity is limited." It is claimed to be one of the four varieties originally obtained by the Dongola people from the Sukkot region, where it is to be found to-day in greater numbers than in Dongola.

A very interesting question of synonymy arises from the fact that among samples of dates collected from near Aswan for Mr. Thomas Brown, horticulturist, of the Egyptian Ministry of Agriculture, was one of a variety called "Bartamoda," which upon careful comparison could not be distinguished from the sample of Bentamoda, which the writer brought from Merowe. Also, in October, 1911, Mr. A. Aaronsohn, acting as agent for Mr. Fairchild, purchased at Aswan, among others, 10 offshoots of "Bartamoda" (under S. P. I. No. 32720).

As offshoots have been brought down the river from Sukkot to the Aswan region for many years, it would have been probable that so fine a variety as the Bentamoda would be among them, and with the carelessness of these people about names, which often pass by word of mouth, the discrepancy in this case is not surprising. As to the meaning of the name as used in Dongola, the writer could get no satisfactory explanation. To the question whether it was from "bint" or "bent," daughter or girl, they insisted that it was neither.

A special trip to Aswan was made early in February, 1914, for the purpose of studying on the ground the question of the identity of the dates known under these two names. A close examination was made of the few trees known as "Bartamoda" to be found near the village, and through the courtesy of the omda samples of the fruit were obtained, so as to settle beyond question the identity of the two (Pl. VII). A very intelligent native gardener, familiar with the trade in date offshoots from the Sudan region, also emphatically testifies that Bentamoda and "Bartamoda" are the same date.

BINT AISCHA.

(Notes taken in Gizeh Garden, Nov. 12, 1913.)

The trees of the Bint Aischa variety are the smallest in the park collection, though the leaves nearly equal those of Samany in length. They are 14 to 15 feet long, with rather slender ribs strongly rounded dorsally and decidedly arched ventrally. The leaves have a distinctly glaucous-green color and are heavily coated with waxy bloom. The spine area is from 2 to 3 feet, the slender, acute spines from one-half inch to 5 or 6 and up to 9 inches in length. They are followed by ribbon pinnæ 2 to 3 feet long, one-half inch to 1 inch broad, and so soft and flexible as to be quite pendulous.

The normal pinnæ are 24 to 28 inches long, 1 to 1½ inches broad, diminishing evenly to 14 or 16 inches long at the apex. The lateral faces of the ribs and attachments of the pinnæ are rather narrow, the pulvini light. Toward the apex of the blade many of the pinnæ have the proximal fold broadened into a wing. The thickness of the pinnæ is 0.017 to 0.018 of an inch.

The orange-colored fruitstalks are of medium size.

The fruits are 1½ to 2 inches long, about 1 inch broad, oval, or broadest at two-fifths of the length from the base, rounding rather abruptly to an obtuse apex. The hard ripe color is near to "Bordeaux" (R. XII), with a conspicuous pale lilac bloom, lighter than "mauvette" (R. XXV). As ripening advances the color deepens to "burnt lake" (R. XII), and from that to nearly black. The outer flesh is then near "raisin black" (R. XLIV), whitening toward the center. The skin then slips readily from the flesh, which is surrounded by a thin, sirupy layer.

The rather small seeds, 1 inch long and one-quarter of an inch broad, are smooth and tapered slightly toward the base. Their color is nearest to "auburn" (R. II). The germ pore is generally one-third of the seed length from the base, the ventral furrow being light and shallow.

The flavor is rich and sweet, and this is a deservedly popular little date. It is quite widely disseminated from Rosetta to Merg, but is nowhere planted as a leading variety.

CORRAGIA.

The Corragia date is a Dongola variety known only from ripe samples obtained at Merowe, on September 24.

The fruits are 1½ to 1¾ inches long, about 1 inch broad, with square blocky base and body diminishing slightly to a broadly rounded apex (Pl. VIII). The rather thick skin is generally closely adherent and the surface thrown in short, coarse reticulations.

The color is rather deeper than "chestnut" (R. II) with a short basal area approaching "mikado brown" (R. XXIX), and there is a pale lavender bloom.

The thin semidry flesh is spongy, with a good deal of tough fiber within. It is "cream buff" (R. XXX) in color. The flavor is sweetish, but lacking in quality. The large smooth stone is 1 inch long, a little more than three-eighths of an inch broad, with broadly rounded ends. The small germ pore is slightly apical, the ventral furrow moderately broad and deep; color, dull "cinnamon brown" (R. XV), shading to "chamois" (R. XXX) at the base. This is a date of fine appearance, which is belied by its thin flesh and third-rate quality.

FALIG.

The Falig date is a variety mentioned by Beadnell¹ as growing in the Khargeh Oasis but was seen by the writer only at Rashida village, in Dakkileh, where it was served as a dessert fruit. A complete description was not obtained.

The fruits are large, having a length of about 2½ inches, long elliptical in outline, color a rich waxy yellow, flesh very rich and sweet, but so soft and sirupy as to be difficult to eat. It is said to keep but a short time.

¹ Beadnell, H. J. L. *An Egyptian Oasis* . . . p. 212-223, 2 pl. London, 1909.

GONDEILA.

(Notes taken at Merowe, Dongola Province, the Sudan, in September, 1913.)

The Gondeila date tree has beautiful, long, tapering leaves with their pinnæ very regular in arrangement, forming a blade nearly open and flat. In general appearance it reminds one of *Arechti* more than of any other variety. The leaves are 12 feet or more in length, the rib moderately heavy, with a graceful taper, the base firm and heavy, strongly rounded dorsally, but little arched ventrally. The spine area varies from 2 to 3 feet; the spines, usually placed singly, are rather weak and scattered. They pass into ribbon pinnæ, 22 to 24 inches long and one-half to five-eighths of an inch broad. Above these the normal pinnæ are 18 to 22 inches long, $1\frac{1}{2}$ to $1\frac{1}{4}$ inches broad, but diminishing toward the apex to 17 or 18 inches in length and one-half to five-eighths of an inch broad. They have a very graceful appearance, are soft in texture, and have no acuteness at the tip.

The pulvini are small and inconspicuous; none are caudate.

The pinnæ form angles of 10° to 15° with the plane of the blade and of 30° to 45° with the axis of the leaf. In grouping, the pinnæ run rather uniformly antorse-retrorse and

antorse - introrse - retrorse, with no higher groups.

The fruit stalks (Arabic "sobata") are very heavy, $2\frac{1}{4}$ inches broad, rigid, 40 to 43 inches long to the head. The fruiting head is 6 to 8 inches long; the strands or "shamrokh" are short, coarse, angled, sprangly, or standing out at strong angles from the heads; all parts are a dull pale orange color.

The fruit, borne on the outer half of the shamrokh, is $1\frac{1}{4}$ to 2 inches long in the

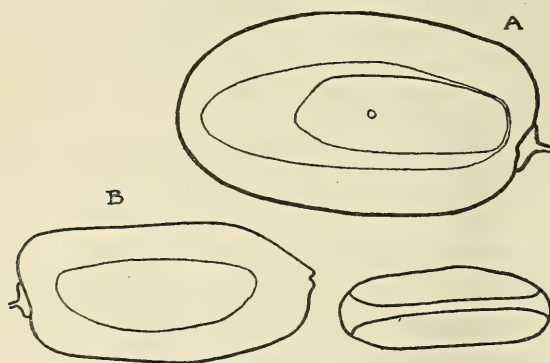


FIG. 5.—Outlines of the Gondeila date from Merowe, Dongola Province, Sudan: A, Freshly ripe; B, cured. (Natural size.)

partly ripe stage, smooth, oval (fig. 5), in color "antimony yellow" (R. XV), the flesh and inner surface being satiny white. As ripening proceeds, the fruit colors to amber brown at the tip and becomes softly wrinkled, the ripening advancing toward the base, which remains a dull yellow when fully ripe. The flesh is then pale-amber colored, a little granular, rich, and sugary.

This is decidedly a fine dry date, the equal of any we have from Algeria. At Merowe on September 21 the last of the fruit had just been cut; the first was ripe 14 days earlier.

Trees of this variety are grown only in small numbers, and the fruit is usually kept for presents or to offer to guests. It reaches Cairo only on special orders.

An ardeb (320 pounds) is priced at 154 piasters (about \$2.40) per 100 pounds.

Inspector of Agriculture W. A. Davie quotes an ardeb of "Gondela" at 100 to 120 piasters (equivalent to \$1.50 to \$1.87) per 100 pounds.

The Gondeila was given by the leading men at Merowe and by Col. H. W. Jackson, Governor of the province, as one of their four chief varieties, ranking next to Barakawi in numbers and importance.

With others this variety is said to have been brought originally from the Sukkot country, which the Dongola people say possessed the date first. Various authorities agree that this date can now be found in small numbers in the region about Aswan, to which country many date offshoots have been brought down the river from Sukkot. A number of trees said to be of this variety were shown to the writer at Aswan in February, 1914.



FIG. 1.—A YOUNG PLANTATION OF HAYANY DATES IN THE DRIFTING SAND NEAR THE MEDITERRANEAN COAST ABOVE RAMLEH.



FIG. 2.—A YOUNG HAYANY DATE TREE NEAR RAMLEH.

Showing how the fruitstalks are lashed to the ribs of the leaves to keep the bunch from thrashing in the strong winds from the Mediterranean.



SAMPLES OF JAOW ISWOD, A MINOR VARIETY OF DATE FROM NEAR MEROWE, SUDAN.
(NATURAL SIZE.)



SAMPLES OF JAOW OBAID, A MINOR VARIETY OF DATE FROM NEAR MEROWE, SUDAN.
(NATURAL SIZE.)



SAMPLES OF KOSHA, THE LEAST KNOWN OF THE FOUR CHIEF VARIETIES OF DATE OF DONGOLA PROVINCE, FROM NEAR MEROWE, SUDAN. (NATURAL SIZE.)

HAMRAWI.

The Hamrawi date is a variety of secondary importance in the Khargeh and Dakhleh Oases, and only a small number of these trees are grown. At El Khargeh it was mentioned that especially fine "agwa" is prepared from them, packed in earthen jars.

The leaves of this variety are long, with light flexible ribs and rather narrow bases strongly rounded dorsally, and dark colored, as though partaking of the dark red nature shown in the fruit. The spine area is long, one-third to two-fifths of the blade length, the spines short, light, and weak. They pass into very narrow ribbon pinnæ. The normal pinnæ are 18 to 24 inches long, $1\frac{1}{4}$ to $1\frac{1}{2}$ inches broad, rather soft in texture. The fruit stalk is short, heavy, and erect, the strands short, the bunch very heavy and compact.

The fruit is about 2 inches long, $1\frac{1}{2}$ inches broad, oblong, with square blocky base and rounding abruptly to a broad obtuse apex. The ripening fruit is nearest to a brilliant "carmine" (R. I), but ripens to a dull purplish color, nearly black. The dark flesh is very soft and sirupy, richly sweet, keeping but a short time after it is fully ripe. The seed is rather small.

A date grown in the vicinity of Bedrashen is known by this name, and of it the fellahin give a similar description, but the writer was unable to see it in fruit and is not certain that it is identical.

HAYANY.

(Notes taken in the vicinity of Merg and Birket el Hadji.)

The Hayany date is a tall-growing variety, but its trunks are usually more slender than those of most of the Egyptian dates (Pl. II, fig. 1). The leaves are usually about 12 feet long and may reach 14 or 15 feet under conditions of abundant moisture and luxuriant growth. The tops are always airy and graceful in appearance, though the rib is moderately strong and has taper enough to give a graceful curve at the tip (Pl. IX, fig. 1). With the free growth induced by abundant moisture, the leaves may curve strongly outward and downward, even to an appearance of drooping. These leaves have an unusually long petiole, or clear space, between the fibrous sheath and the first spines, which sometimes amounts to 15 or 18 inches. The base is broad and thin, narrowing abruptly to a moderate-sized rib. The spine area is about 30 inches, and the slender, acute spines range in length from 1 inch for the lowest to 7 or 8 inches where they pass into the strikingly long narrow ribbon pinnæ, which may be 24 to 36 inches or more in length, while they are only one-half or three-fourths of an inch wide. From these the pinnæ diminish in length and increase in width until at 9 or 10 feet from the base they are 18 or 20 inches long and $1\frac{3}{8}$ to $1\frac{1}{2}$ inches broad, rounding off the end of the blade with a length of 14 to 16 inches. In the lower portion of the rib the lateral faces are narrow, but they become quite broad at from 8 to 10 feet. The lower pinnæ and some of the upper spines are contracted near the base into an oval solid "neck" from half an inch to 2 inches in length. While this may occur to a limited extent in some other varieties, it is a character so far always found occurring in the Hayany. The pinnæ are placed so as to form a rather smooth open blade, and the open spacing of the long lower pinnæ gives to these tops an airy lightness that is very pleasing.

The orange-colored fruit stalks are 3 to 4 feet long, of medium weight, and rather flattened in cross section. The strands (shamrokh) are of medium length and weight, the fruit being borne on their outer half.

The compact bunches of brilliantly colored fruit, hanging like huge tassels below the vase-shaped crown, make a grove of these trees a very striking sight. In the coast region the lashing of the fruit stalks to the bases of adjacent leaves to prevent the thrashing of the bunch in the gales is a cultural practice which is illustrated in Plate IX, figure 2. The fruits are 2 to $2\frac{1}{2}$ inches long and 1 to $1\frac{1}{4}$ inches broad, the broadest portion being usually a little below the middle; some fruits are often a little

curved and unsymmetrical. They taper gradually toward the broadly rounded apex (fig. 6).

The color of the fruit, as it is gathered, hard ripe, is dull "carmine" or near to "Nopal red," with blotches of "ox-blood red" (all R. I). The flesh is then nearly white, brittle, juicy, sweet, with considerable astringency. In ripening, the color of the fruit drops to a shade close to "Hay's maroon" (R. XIII) and to a dull unattractive shade, as near "dull purplish black" (R. L) as anything.

In the ripe fruit the rather thick smooth skin is easily slipped off and between it and the rather soft outer flesh is a thin sirupy layer. The outer flesh is of a "tawny olive" color (R. XXIX), with a firmer, slightly fibrous interior of "colonial buff" color (R. XXX). The whole thickness of the flesh is about one-fourth of an inch. The flavor is moderately sweet, not cloying, but lacking in distinctive quality or "bouquet."

The seed is large, $1\frac{1}{4}$ to $1\frac{3}{8}$ inches long, three-eighths of an inch broad, oblong or slightly wedge shaped, with broadly rounded ends, sometimes slightly recurved. The ventral furrow is broad and deep. In most specimens the germ pore is about three-eighths of an inch from the base, but in some seeds it is central. An examination of the fruit of individual trees would be needed to show the extent of these variations. The color of the seed varies from "wood brown" or "buffy brown" (R. XL) to near "antique brown" (R. III).

As well as the writer can judge from memory of more than a year, the flavor of these Egyptian Hayany dates is not as rich and sweet as those of the same variety grown under the name of "Birket el Haggi" in the heavier soil and under the hotter sun of the Cooperative Date Garden of Tempe, Ariz. The enormous quantities of this date gathered in the unripe stage and consumed in Egypt by people of all classes is undoubtedly the result of a taste for which, as yet, the American people have developed no equivalent. The great region of the Hayany date is that of the coastal dunes and sandy delta land from Alexandria through Ramleh and Edku around to the lands bordering the Nile below Rosetta. The second region is the border land between the delta proper and the desert, represented by Birket el Hadji, Merg, Korain, Fakus, and Salihieh. There are a few small districts bordering the desert west of Cairo where this variety is growing, and new plantings are being made above the Pyramids. The latter regions being much hotter and earlier, the crop ripens there first, and fruit from some of these points was brought into the Alexandria markets on September 2. The distribution of the fruit seems to be pretty general among the smaller towns, as well as the cities, and the heavy production is handled with very little waste. By the time the earlier regions are cleared up the crop from the coast region begins to move. The first Hayany dates from the coast were noticed in Cairo on November 7, and they continued to come in for about 30 days.

The Zagloul and the Samany varieties came in with the Hayany in the latter part of the season, and the Samany continued to appear for about 10 days after all the Hayany fruit had gone; in fact, until the shortening supply was taken by the Alexandria market. At Korain, a small proportion of the Hayany dates are made into "agwa." After being allowed to become fully ripe the skins are slipped off and the seeds removed, after which the fruit is spread in the sun and dried for a few hours. They are then kneaded and worked over several times until the mass becomes a smooth, homogeneous paste, which is then packed into earthen jars and tightly sealed.

The Hayany fruits seen in the markets of Alexandria and Cairo, as well as upon the trees at Ramleh, Edku, Rashid, Merg, and Birket el Hadji, showed marked differences in size and form. While the general type is rather constant after allowing for variations due to the different qualities of soil and amount of water received, there remain variations too great for such explanation. It is more than probable that a good many seedling trees which have appeared from time to time bearing a close

resemblance to their Hayany parent, along with their offshoots, have been incorporated under the name of Hayany and that now it would be impossible to always distinguish the original type from them.

The earliest introduction of this variety into the United States was through Mr. David Fairchild. The shipment was from Alexandria in the spring of 1901. Two offshoots with this name, under S. P. I. No. 6438, were planted in the Cooperative Date Garden at Tempe, Ariz. Of the same shipment one tree, labeled "Dakar Majahel," S. P. I. No. 6442, was very tardy in flowering, but finally proved to be Hayany or a near equivalent. Of a shipment of offshoots secured through Mr. Fairchild from Mr. Em. C. Zervudachi, in October, 1901, six trees were labeled "Birket el Haggi" and were planted at Tempe, under S. P. I. No. 7635. Three other trees of the same lot, from which the labels had been lost, were planted without S. P. I. numbers and as soon as they fruited were identified by the writer as being the same as those under No. 7635.

Studies made by the writer from 1909 to 1912 established clearly the identity of these "Birket el Haggi" trees with the trees labeled Hayany, and probably also of the No. 6442, though its very tardy fruiting is not characteristic of the variety. As the variety has been a vigorous grower, prolific in

offshoots, and productive of a fruit which, if not of the highest quality, contains more sugar than it develops in Egypt, it has been very popular with the people of the Salt River Valley. It soon attracted rather widespread notice and has been more highly indorsed by the staff of the Arizona experiment station as a variety likely to be more profitable under their conditions than any other date tested in the Tempe Garden. All this exploiting has been under the name of "Birket el Haggi," frequently shortened to "Birket" as more convenient and euphonious. It was natural, then, to wish to learn not only the correct name of this date, but its home in Egypt and under what conditions it grows to the best advantage. The only published reference to the "Birket el Haggi" as an Egyptian variety is in the paper by Delchevalerie,¹ a former gardener of the khedive, who described it as a very rare variety "sweet and sugary and of a reddish color," and called it "the earliest fruiting date tree in all Egypt," giving fruits from the second year of planting. Repeated visits by the writer to the villages of Merg and Birket el Hadji, near the shores of the old "Pool of the Pilgrims," brought out the fact that they have no date variety called "Birket el Haggi," but that the early-ripening Hayany reach the Cairo market under this local name, as we in America speak of "Chautauqua grapes" or "Riverside oranges." That in a foreign country and with a foreign tongue such a local designation should be mistaken for a varietal name is easily understood. Delchevalerie's description of "Birket el Haggi" is meager in details, but corresponds well with Hayany, though his account of Hayany in the same publication is wholly

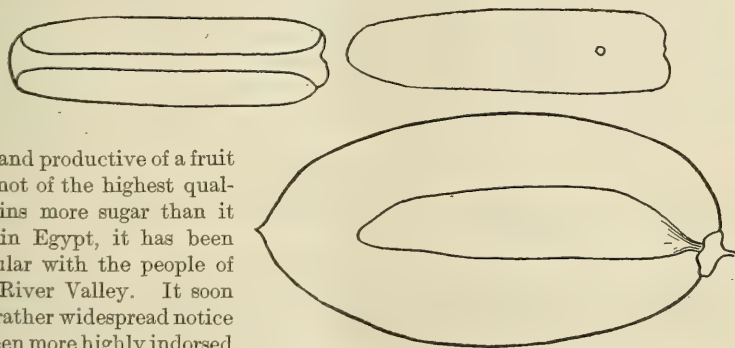


FIG. 6.—Outlines of the Hayany date in "rutab" (fresh) condition, seen in the market of Merg, December 7, 1913; shipped from Alexandria, Egypt. (Natural size.)

under the name of "Birket el Haggi," frequently shortened to "Birket" as more convenient and euphonious. It was natural, then, to wish to learn not only the correct name of this date, but its home in Egypt and under what conditions it grows to the best advantage. The only published reference to the "Birket el Haggi" as an Egyptian variety is in the paper by Delchevalerie,¹ a former gardener of the khedive, who described it as a very rare variety "sweet and sugary and of a reddish color," and called it "the earliest fruiting date tree in all Egypt," giving fruits from the second year of planting. Repeated visits by the writer to the villages of Merg and Birket el Hadji, near the shores of the old "Pool of the Pilgrims," brought out the fact that they have no date variety called "Birket el Haggi," but that the early-ripening Hayany reach the Cairo market under this local name, as we in America speak of "Chautauqua grapes" or "Riverside oranges." That in a foreign country and with a foreign tongue such a local designation should be mistaken for a varietal name is easily understood. Delchevalerie's description of "Birket el Haggi" is meager in details, but corresponds well with Hayany, though his account of Hayany in the same publication is wholly

¹ Delchevalerie, G. *L'arbre national des Égyptiens. Le dattier. Sa description, son histoire, sa culture, sa multiplication et son emploi dans les arts, l'industrie, la médecine et l'économie domestique.* In *Bul. Féd. Soc. Hort. Belgique*, 1871, p. 170, 1872.

in error. How he should have overlooked the real Hayany, the most numerous and popular date in the Egyptian delta, is difficult to understand.

The essential points of the discussion are that there is no such date variety as "Birket el Haggi" and that the trees received from Mr. Zervudachi under that name and planted in the Tempe Garden under S. P. I. No. 7635 are Hayany, identical with those of the earlier importation by Mr. Fairchild under S. P. I. No. 6438.

JAOW ISWOD.

A Dongola variety known only from samples of the fruits, which were procured from near Merowe in a ripe condition on September 24.

The fruit is oblique and unsymmetrical, $2\frac{1}{4}$ to $2\frac{1}{2}$ inches long, seven-eighths of an inch to 1 inch broad, the broadest portion being slightly above the base, from which it tapers gradually to a rather blunt apex (Pl. X). The thick skin is closely adherent, coarsely wrinkled longitudinally, with some smaller cross reticulations. The basal portion is colored "carob brown" (R. XIV), with the apical portions more nearly "chestnut" (R. II).

The semidry flesh is about one-fourth of an inch thick in the thickest portions and is "cream buff" (R. XXX) in color. The sweetish flavor is suggestive of dried sweet apples. In keeping qualities this variety seems about perfect. The oblong seed is about seven-eighths of an inch long, five-sixteenths of an inch broad, somewhat flattened, broadly rounded at either end, the germ pore rather nearer the apex, the ventral furrow narrow and deep; color near to "tawny olive" (R. XXIX), shading to "clay color" (R. XXIX).

JAOW OBIAD.

A Dongola variety of the dry type known only from samples of the ripe fruit, which were procured at Merowe on September 24.

Fruits broadly ovate, somewhat oblique and unsymmetrical, $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long, three-fourths to seven-eighths of an inch broad, the shining surface being broken by well-marked but rather fine reticulations, the basal portion sometimes smooth (Pl. XI). The color is difficult to place, owing to a translucence, but may be described as between "chestnut" and "burnt sienna" (R. II), or sometimes more nearly "amber brown" (R. III), with the basal one-third often close to "honey yellow" or "chamois" (R. XXX). Many of the fruits show a faint lavender bloom.

The firm flesh, one-eighth of an inch thick, is "cream buff" (R. XXX) in color, with an agreeable flavor of honey wafers and no suggestion of astringency.

The oblong seeds are three-fourths of an inch long, three-eighths of an inch broad, nearly smooth, the ends broadly rounded, the apex often apiculate. The germ pore is placed slightly apically and the ventral furrow is narrow and rather deep. The color may be called a dull "snuff brown" (R. XXIX), with the basal portion "chamois" or "cream buff" (R. XXX).

Examined June 1, or more than 8 months from ripening, these fruits were found in perfect condition.

KOBI.

One of the latest dates to come to the Cairo market from Edku and Rashid is the Kobi variety. The trees are not grown in large numbers and the fruits are shipped hard ripe in date-leaf crates to be consumed fresh. They were seen in Cairo from December 16 to 20. The fruits are about $1\frac{1}{4}$ inches long and seven-eighths of an inch broad, the greatest diameter at a little above the middle, from which they contract abruptly to a broadly rounded apex. The color is close to "amaranth purple," ripening to a "blackish red-purple" or "burnt lake" (all R. XII). The rather brittle flesh is sweetish, but without character, and it ferments readily during ripening.

The oblong seed is about seven-eighths of an inch long, three-eighths of an inch broad, slightly rough, with broadly rounded ends. The apical portion is colored from

"russet" to "Mars brown" (R. XV), with the base close to "chamois" or "cream buff" (R. XXX). The germ pore is usually placed centrally and the ventral furrow is narrow and shallow.

This variety is of value only as it prolongs the season of fresh dates.

KOSHA.

This belongs to the dry-date class, and the fruit only was seen, and in the dry condition.

Fruits $1\frac{1}{2}$ to $1\frac{3}{4}$ inches long, three-fourths to seven-eighths of an inch broad; distinctly compressed, oblique and unsymmetrical, sometimes slightly curved, broadest at about one-third above the base, tapering rather abruptly to an obtuse apex (Pl. XII).

The surface, with nearly smooth or slightly wrinkled areas, broken by areas of fine longitudinal folds with cross reticulations. The color is somewhat mottled, the darker portions being "bay" (R. II), with an area around the base of "sorghum brown" (R. XXXIX) and lighter patches of "clay color" (R. XXIX).

The fine granular flesh is "honey yellow" in the darker parts and "cartridge buff" (R. XXX) within. The flavor is remarkably sweet for a dry date, with the usual wheaty flavor and no trace of astringency. The quality will rank as excellent.

The seeds are seven-eighths of an inch to 1 inch long, about five-sixteenths of an inch broad, tapering toward the slightly apiculate apex, often with sharp lateral ridges or "wings." The small germ pore is usually about central, the ventral furrow being rather narrow and deep. The color of the seeds is nearest to "wood brown" (R. XI).

The sample of this fruit was included in a lot obtained at Merowe on the eve of departure from Dongola Province. The whole collection was mailed to Washington and the description of the varieties was not made till after the writer's return.

This variety is regarded as one of the best dry dates yet sampled, and steps will be taken to secure offshoots of it at a later date.

KULMA.¹

The Kulma date is counted as one of the four chief varieties originally received into Dongola from Sukkot country. The leading men of Merowe say that this variety should not be planted near the Nile bank, where its roots will get too much water, but farther inland, where it will be sparingly irrigated.

The only tree seen² had a rather short, heavy trunk and dense, broadspreading top. The leaves are 10 to 12 feet long, with stout ribs carrying their size well out toward the apex, where there is but a slight flexibility. The foliage is bluish green with heavy waxy bloom. The spine area is 18 to 24 inches, the spines heavy, acute, from 2 to 7 or 8 inches long, passing to stiff acute spike pinnæ 18 to 20 inches long, one-half to five-eighths of an inch broad. At about 36 to 40 inches from the base they pass into the normal pinnæ, which are 16 to 18 inches long and $1\frac{1}{2}$ to $1\frac{3}{4}$ inches broad. They diminish in size but little till near the apex, where the pinnæ are 10 to 12 inches long and 1 to $1\frac{1}{4}$ inches wide. The spines and spike pinnæ are set at divergent and defen-

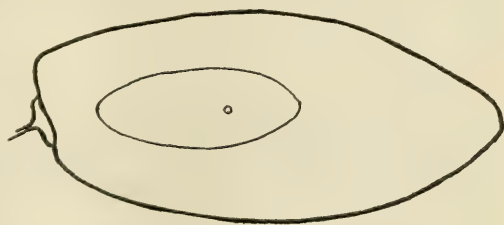


FIG. 7.—Outlines of the Kulma date in fresh, ripe condition; from the governor's garden, Merowe, Dongola Province, Sudan. (Natural size.)

¹ In Burekhardt's vocabulary of the "Noubia" language, "kulma" is the transliteration for "big," and the name may be descriptive of the size of this variety. (Burekhardt, J. L. Travels in Nubia. Ed. 2, p. 145. London, 1822.)

² Only two offshoots were secured of this variety. One, from the tree in the Mudirich Garden at Merowe, from which the description was made, was the gift of Col. H. W. Jackson, governor of Dongola Province. The other was the gift of Omda Mohammed Ahmed Ibrahim.

sive angles, about which the pinnæ fall into four rather regular ranks, with the valley of the blade broad. In the apical portion, the pinnæ fall mostly into two ranks, lying nearly parallel at an axial divergence of about 45°.

The fruits are $2\frac{1}{2}$ inches long, $1\frac{1}{8}$ inches broad a little above the middle, and taper to a narrower base and an obtuse apex (fig. 7). Their color is yellow, ripening to a dull "bay" (R. II), with the basal portion "honey yellow" or "Isabella color" (R. XXX). The rather soft flesh is a dull amber color, the inner portion satiny white with a large amount of tough fibrous "rag." The flavor is so rich as to be rather cloying, though of a quality which would be attractive to many people. The rather broad oval seed is about 1 inch long, corrugated, the germ pore placed somewhat apically, the ventral furrow being narrow and shallow.

From its large size, fine appearance, and rich flavor this little-known date is worthy of a careful trial, though before it could be ranked as a first-class variety cultural conditions would have to be developed which would eliminate the large amount of tough fiber.

SAIDY.

(Saidi, Wahi.)

Trees with heavy trunks and stiffly spreading leaves 10 to 14 feet long (Pl. IV, fig. 1), the heavy ribs with very broad bases.¹ There is a space of clear petiole of 12 to 15 inches below the first spines. The rib is strongly rounded dorsally and tapers but slowly, its outcurve being stiff rather than graceful.

The spine area is from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet, the spines of medium weight or quite heavy, placed singly and rather scattered, from 2 inches long below to 7 or 8 inches in the upper area, and passing into a stiff ribbon pinnæ or spike pinnæ 20 to 24 inches long and one-half to three-fourths of an inch wide. The normal pinnæ following these at 4 to 5 feet are 20 to 24 inches long and $1\frac{1}{4}$ to $1\frac{5}{8}$ inches wide, but dropping steadily in length to 12 to 14 inches near the apex. Their greatest width of $1\frac{1}{2}$ to $1\frac{3}{4}$ inches is reached at about three-fourths of the blade length from the base. The pulvini are unusually heavy, deeply cream colored, or slightly brownish in exposed places. The pinnæ are rather coarse and harsh, 0.018 to 0.019 of an inch or sometimes 0.025 of an inch thick and conspicuously bluish green with a heavy waxy bloom. This bluish-green color is very noticeable when the leaves are seen in a mass.

The 4-ranked arrangement of the pinnæ is conspicuous, and the narrow axial angles and strong angles with the blade plane formed by the lower antrorse pinnæ give the leaf a bristling and formidable appearance. The valley is close and narrow nearly to the apex of the blade. The pinnæ groups are of the normal types till quite near the apex, and the paired groups of the antrorse-retrorse type are largely in the majority.

The orange-yellow fruit stalks are strikingly long, of medium weight, or rather heavy in some cases.

The fruit ² is $1\frac{1}{2}$ to $1\frac{5}{8}$ inches long, seven-eighths of an inch to 1 inch broad, blocky, with broad square base rounding to a broad obtuse apex (Pl. XIII). The skin is rather coarsely wrinkled both longitudinally and transversely and partially loosened from the flesh. The darker portions of the flesh have a translucent appearance and are nearest to "liver brown" (R. XIV) in color, with a delicate lavender bloom.

A basal zone of about one-fourth the length of the fruit is a "tawny olive" (R. XXIX) and is opaque in appearance. The flesh is three-sixteenths of an inch thick, firm, slightly granular, somewhat sticky; an outer zone of one-third of the thickness is of the exterior color, while the nearly transparent inner portion is close to "olive ocher," (R. XXX) with a little more suggestion of green.

The flavor is heavily sweet, rich, and a little cloying, but of the quality usually sought after by date purchasers in this country. After being packed seven months

¹ Notes made near the Temple of Nadurah, Khargeh Oasis, October 8, 1913.

² Described from fruit packed in cartons at Sheik Abu Bakr's, Rashida, Dakhleh Oasis, Oct. 18, 1913.

the quality is in no way impaired, and where not reached by weevils these dates would sell as well as at Thanksgiving time. No variety has been tried that stood the test better (Pl. XIV).

The seeds are five-sixteenths of an inch to 1 inch in length, three-eighths of an inch broad, smoothly rounded, the germ pore nearly central, the ventral furrow narrow and shallow, the color close to "tawny olive" (R. XXIX).

The fruits, packed in paper boxes and rather dry, averaged 35 to 40 to the pound. The percentage of seed weight to the total weight of fruit is 11.6, a ratio too high to mark this date as of absolutely first quality, yet with its other good qualities a great deal can be allowed in this respect.

These fruits ripen in the heat of the Libyan oases in October. Whether they will find sufficient heat for their perfection in any portion of the United States outside of the Salton Basin is perhaps doubtful. Temperature records of only one of these oases have been kept. A record of seven years at Dakhleh (Table I), shows a mean annual temperature of 74° F., which is slightly higher than that of Palm Springs, Cal.; and for the growing months of February to October, inclusive, a mean of 78.40° F. The summation of heat units is about the same as that of Tuggurt (Tougourt) in Algeria (table on p. 8), which suggests about the same temperature requirements as for the Deglet Noor. This indicates that this variety may be expected to reach maturity in the United States only in the heat conditions afforded by the Salton Basin of California or in the hot lower portion of the Colorado Valley from Needles to the Mexican line.

This variety, as seen by the writer, is the great export date of Khargeh and Dakhleh oases, and Sheik Abu Bakr, of Dakhleh, is authority for the statement that it is the chief date of the entire chain of oases of the Libyan Desert, from Siwah at the northwest, which lies about 400 miles southwest of Cairo, through Baharieh, Farafreh, and Dakhleh to Khargeh, the most southeasterly, lying 120 miles due west of Luxor.¹

They have together an extreme north to south range of about 300 miles through a practically rainless region of dry air and intense desert heat. Siwah is said to be 78 feet below sea level. The other oases of the chain lie at elevations ranging from near sea level to three or four hundred feet above. Only Khargeh has railway connection with the Nile Valley; from the other oases the dates reach the Nile Valley by camel caravans commanded by Bedouin traders who buy the entire export crop of the desert people at their gardens.

The common occurrence of this date as the leading variety of the widely detached oases, while it is unknown in the Nile Valley,² suggests that they have had it in possession a long time, perhaps dating back to a period when allegiance to the Egyptian Government was not acknowledged and when communication was much more free and regular by the desert trails between the oases than that between the oases and the Nile Valley.

In the enumeration of the taxed date palms of Upper Egypt for 1907 the oasis of Baharieh is credited with 98,996, Dakhleh with 106,344, and Kargeh with 65,521, or a total of nearly 271,000 trees. Siwah and Farafreh are not reported.

From observations in Kargeh and Dakhleh and from the crop seen coming in from Baharieh, the writer is satisfied that considerably more than half of the trees in these three oases are of the Saily variety, so that a low estimate would give 150,000 or 200,000 of these without including Siwah Oasis, where it is known to be the chief tree.

¹ Siwah is approximately 25° 30' east of Greenwich and in 29° north latitude. Baharieh is crossed by the meridian of 29° and lies just north of 28° latitude. Farafreh lies close to the intersection of the meridian of 28° and the parallel of 27°. Dakhleh lies about equally on either side of the meridian of 29° and at about 25° 30' north latitude. Khargeh lies with its greatest extent north and south about 30° 40' east and from 24° 30' to 26° north latitude (Pl. I).

² Unless the Siwah of Gizeh Province proves to be identical.

A very interesting bit of exploration history attaches to the procuring of this variety. Mr. David Fairchild, in an agricultural exploration of Egypt in 1901, purchased in Fayum a quantity of dates which he regarded as the finest he had seen in Egypt and which he was told were "Wahi" from the village of Siwah in the oasis of Baharieh. Though it was known to Mr. Fairchild that the term "Wahi" had reference to the oasis, it was supposed for many years that this was the varietal name of the date, and three different men had been dispatched with commissions from the Office of Foreign Seed and Plant Introduction to procure offshoots of this desirable variety. During the writer's trip to Dakhleh Oasis he learned from Sheik Abu Bakr that Saidy, the export date of the Libyan oases, is sold by the Bedouin traders when they reach the Nile Valley as "Wahi," the date from "el Wah," or the oasis. Samples of the fruit, purchased in the markets of Wasta, in Fayum, and directly from the traders under the name of "Wahi," proved perfectly identical with samples of Saidy brought from Dakhleh and Khargeh, establishing beyond question the Saidy as the long sought "Wahi." Though 108 Saidy offshoots were purchased in Khargeh on this trip, the first introduction of Saidy offshoots dates from the purchase through Mr. H. A. Rankin, S. P. I. No. 11485, in 1904, said to be "from Fayum." As this variety is not known in the Fayum country, it is probable that Mr. Rankin secured the offshoots through Bedouin traders from the oasis of Baharieh, between which points there is constant traffic.

Another interesting phase of the whole discussion is the very close resemblance, if not the absolute identity, of the Saidy with the Siwah grown in the upper sections of Gizeh Province.

SAMANY, SAMIANI, OR RASHEDI.

(Trees noted in the Gizeh Garden; fruit in Cairo markets from Edku.)

The Samany date is one of the most striking and characteristic varieties of Lower Egypt, and, by the natives, it is counted one of the best.

The trees are very heavy bodied, not as tall as Zagloul, and have longer leaves than any variety the writer has ever measured—16½ feet being the length of one specimen, seemingly not above the average. The ribs are very heavy and strongly rounded at the base, sometimes 12 to 14 inches broad at the attachment with the trunk, and taper to the apex so as to give a heavy but graceful curve to these immense leaves, which are rather wide apart, forming an open crown. There are 12 to 16 inches of clear petiole below the spines. The long, slender, acute spines occupy about 3 feet of the rib; the long, rather soft pinnæ are arranged quite evenly, giving a broad, nearly smooth open blade with the breadth carried well out to the soft, flexible tip. In the group arrangement of the pinnæ the antrorse class disappear at about the middle of the blade, leaving the outer portion largely dominated by the introrse pinnæ, which form angles of 40° to 58° with the axis. As a variety to afford an imposing ornamental tree, in addition to producing a desirable fruit, nothing finer than this can be selected from the Egyptian list.

In fruit this variety is easily the most striking and peculiar of all the delta varieties. The heavy compact bunches are borne unevenly on coarse, strong strands, or "sham-rokh." The fruits are about 2 to 2½ inches long, 1½ inches broad, rather oblique, and inclined to be oblong for about two-thirds of the length, when the diameter is reduced so abruptly as to form a sort of shoulder on the outer side, and it narrows to an obtuse, unsymmetrical apex (fig. 8).

The ground color of the fruit is close to "orange-buff" (R. III) or "Capucine orange" (R. III), shaded, mottled, and streaked longitudinally with a color for which "pomegranate purple" (R. XII) is the nearest definition, yet hardly satisfactory. This describes the hard, half-ripe, or "rutab," state in which this date is always marketed. The flesh is then firm to brittleness, white, fine grained, juicy, mildly sweet, with scarcely a trace of astringency or tannic-acid flavor. In this stage it is greatly relished



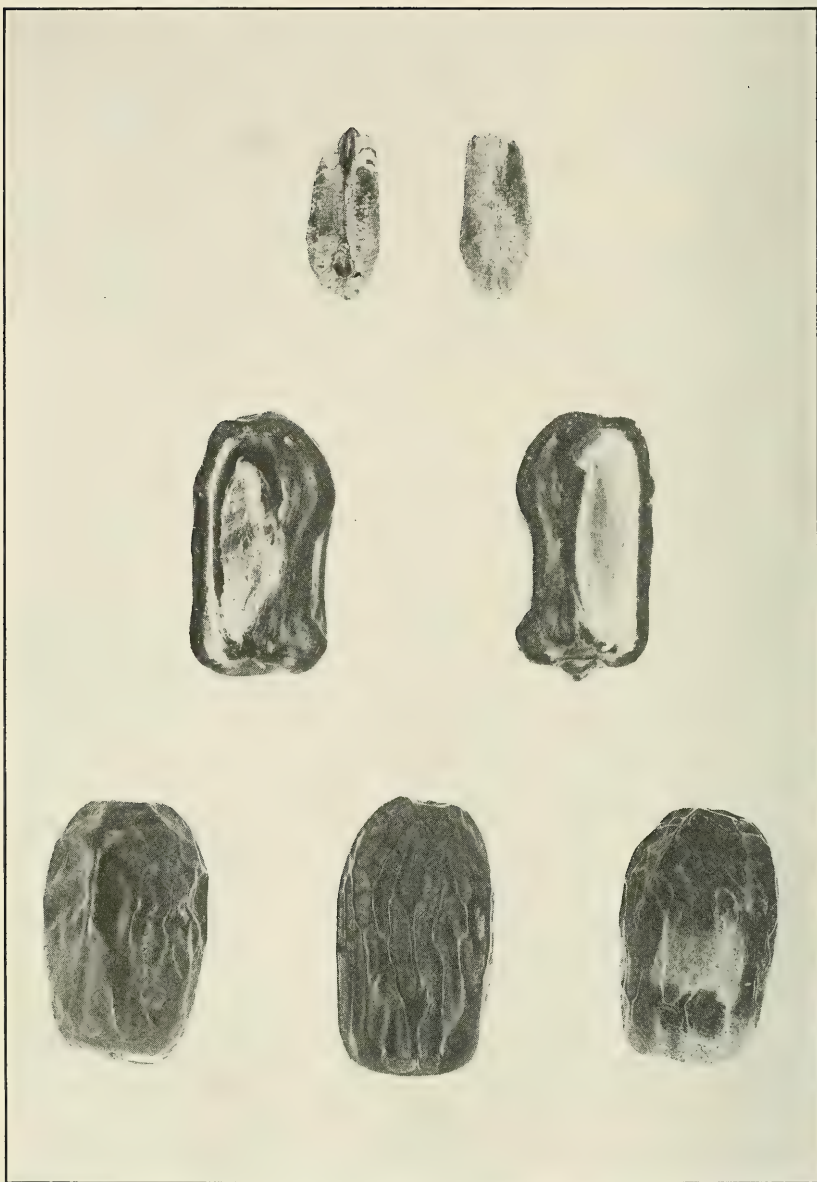
SAMPLES OF PACKED SAIDY DATES FROM THE DAKHLEH OASIS. (NATURAL SIZE.)



SAMPLE BOX OF SAIDY DATES FROM THE DAKHLEH OASIS, AS PACKED BY THE CORPORATION OF WESTERN EGYPT.



SAMPLES OF SULTANY DATES FROM THE DAKHLEH OASIS. (NATURAL SIZE.)



SAMPLES OF TAMR DATES FROM THE KHARGEH OASIS. (NATURAL SIZE.)

by the Egyptian people, apparently in much the same way as they like a stalk of sugar cane. In a ripe state this date is a disappointment, both as to appearance and as to quality.

It ripens to an unattractive, nondescript color, as near "purple-drab" as to anything, and mottled with "dark purple-drab" (both R. XLV). The very thin skin wrinkles slightly, slipping with some difficulty from the flesh, from which it is parted by a thin layer of sirupy sap.

The color of the flesh is a pale "honey yellow" (R. XXX), nearly white at the center, and with some "rag" surrounding the seed. The flavor is insipid, and it ranks very low in keeping quality, not containing sugar enough to prevent quick souring. The seed is coarse and rough, in the partially ripe fruit completely filling the cavity. Its germ pore is placed slightly nearest the base, and the furrow is broad and shallow.

This variety is a good deal planted in private grounds about Alexandria and Ramleh, but the only regions of its culture on a commercial scale are about Edku and Rashid, the native name for Rosetta. While some of these plantations are within reach of irrigation water, more frequently they are grown in dune slopes of pure sand, where the roots readily reach a brackish ground water (Pl. II, fig. 2). The cool, humid climate of the coastal region seems especially favorable to this succulent variety, which is one of the latest to mature.

In some of the Cairo fruit stores glazed dates were on sale in fancy cartons, prepared by a Greek firm in Alexandria, which, from the peculiar form of the fruit, could have been no other than this variety.

The offshoots of the Samany command the highest prices of any variety in Egypt for the reason that they are in great demand for planting in the gardens of new country and suburban places which are being built up around Alexandria. But few of this variety have been planted around Cairo. The only ones observed are in the Gizeh Garden, next to the Zoological Gardens and formerly a part of the palace grounds of Ismail Pasha, where they are planted along avenues with Zagloul, Bint Aischa, and several other varieties.

SIWAH (SIWI).

(Notes made near Hauamdiyh, November 5 and 17, 1913.)

Trees of the Siwah date have large heavy trunks with coarse scales from the leaf bases and heavy, stiffly spreading tops. The leaves are 14 to 15½ feet long, with very heavy bases, strongly rounded lower rib, which tapers gradually but still remains stiff and heavy at the apex. The spine area is from 2½ to 4 feet, the spines very strong and heavy, bluntly acute, from 2 to 8 or 9 inches long. The stiff, coarse pinnae following these are 24 to 29 inches long and 1 to 1½ inches broad. They diminish regularly in length toward the apex and increase in breadth up to 10 or even 11 feet from the base, being usually 17 to 20 inches long and 1¾ to 2 inches broad at 8 to 10 feet from the base and 11 to 14 inches long and 1¼ to 1½ inches broad at the apex. Many of the upper pinnae have the proximal fold broadened into a wing and are decurrent. The pulvini on the spines are unusually heavy and dark cream colored, being somewhat lighter on the less exposed pinnae. For the first 6 feet of the blade the pinnae comprise only

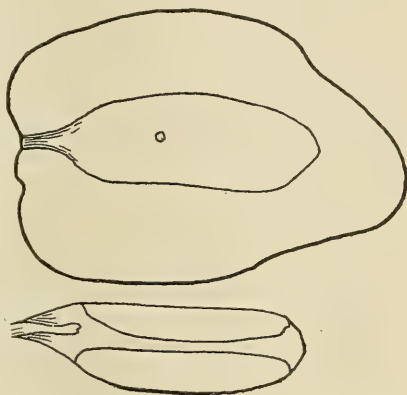


FIG. 8.—Outlines of the Samany date in "rutab" (fresh) condition, on the Cairo market, November 16, 1913; shipped from Edku, on the Mediterranean coast. (Natural size.)

the antrorse and retrorse classes in the paired antrorse-retrorse groups, above which the introrse pinnae appear, and also the triple (antrorse-introrse-retrorse) groups with a few quadruple (antrorse-introrse-introrse-retrorse) groups. In the outer 2 feet of the blade the introrse class predominates, or all classes become merged. The 4-ranked arrangement of the pinnae in the blade is strongly maintained, but is especially pronounced in the lower portion, where the bristling ranks of the antrorse pinnae vary strongly from those of the retrorse and give to the leaf a strong attitude of defense. The remarkably long and heavy orange-colored fruitstalks of this variety are almost identifying in their character. They may be $2\frac{1}{2}$ inches in diameter and 50 to 60 inches long to the fruiting head, or portion bearing the strands, or "shamrokh." The fruiting head is 16 to 24 inches long, bearing strands 24 to 40 inches long upon only the outer 12 to 18 inches of which the fruit is borne, the basal portion being straight and irregularly four sided.

The fruit is $1\frac{3}{8}$ to $1\frac{1}{2}$ inches long, 1 inch broad, oblong or slightly broadest a little beyond the middle, with a rather square blocky base and obtusely rounded apex. The color of the fruit on the tree is a brilliant yellow, not far from "wax yellow" (R. XVI) or "light cadmium" (R. IV). The fruits are picked before they are fully ripe and are dried in the sun on a hard earthen floor, or the floor may be spread with a thin layer of date leaves. The first quality of fruit ripens to a color near "hazel" (R. XIV) or "tawny" (R. XV), but it is semitransparent except the basal portion, which is often opaque and of a "honey yellow" or "chamois" color (R. XXX). Fruits of a very good quality may be considerably darker, close to "bay" or "chestnut" (R. II), but either class held against the light will show the seed through the flesh quite plainly. The skin is very thin and transparent, and the outer portion of the flesh is of the same shades given for the outside appearance, while the inner flesh is considerably lighter. In good "agwa" that has been packed several months the outside of the fruit is shiny, as though dipped in a sugar sirup, and is a little sticky.

The flesh is less sticky than the outside and a good deal granular. The flavor is a rich sugary sweet, with a suggestion of caramel, and very agreeable.

The seeds, large for the size of the fruit, are about three-fourths of an inch to 1 inch long, three-eighths of an inch broad, roundish in cross section, and may be called oblong oval in form, a little broader in the middle and with broadly rounded ends. The germ pore is about central, the ventral surface a little corrugated, the furrow narrow and shallow. The color is close to "wood brown" (R. XL).

When sufficiently cured the dates are packed solidly into strong, deep, circular baskets made from the braid of date-leaf pinnae sewed spirally, and a cover of the same material is stitched closely on. The whole mass thus inclosed becomes sealed with the exuding sirup of the sticky dates and is practically air-tight. If cleanly and sanitary methods could be followed, there is no doubt that this method of packing is an excellent one, and there is reason to believe that a curing process goes on in the mass which gives a flavor and texture of flesh not secured when the individual dates are packed in their natural shape in paper cartons without compressing and so exposed to the air.

The rather large seed is all that prevents this date from being classed as a strictly first-class variety, judged by its actual merits as a date. That the product that goes on the market is not above third class needs only a view of it in the market stalls to prove. One has but to see the yards and the curing and packing in progress to be convinced that such a product is the only possible result of the antiquated and filthy, not to mention insanitary, methods employed. Dried on the bare, dust-covered ground or on a floor thinly spread with date leaves, covered with flies, swept with the dust of passing traffic, finally tramped with the naked feet into the huge date-leaf sacks, the writer was not surprised to learn that the wholesale price realized for these dates by the grower is only about 4 or 5 millièmes to the rotl, the equivalent of 2 or $2\frac{1}{2}$ cents per pound.

In December the retail price of the Siwah in the native markets of Cairo was 1 piaster per rotl, while at the same time in the best fruit and provision stores, patronized by European customers, there was an active trade in the Algerian Deglet Noor, in fancy packages labeled "Dattes Muscades," at prices the equivalent of 5 piasters per rotl. From samples of Siwah dates obtained from private sources, carefully selected and packed for home use, the writer is convinced that the first quality of dates, packed in a modern and attractive way, would be competitors with the Algerian dates on at least an equal footing and would be the choice of many people of refined taste. Of course, not all of the Siwah crop could be converted into a first-class pack under the best of conditions, but a sufficiently large proportion, with proper methods, could be brought up to the first quality to make the difference in price between 1 piaster and 5 piasters per rotl run into a good many thousand pounds sterling for a year's output. What the French in Algeria and Tunis have done to improve the date output of those countries, what is recently being done with the dates of the Persian Gulf region, ought not to be beyond accomplishment for Egypt with such dates as the Siwah and the Saidy for a foundation.

A question of nomenclature comes in here which is rather typical of the whole date situation in Egypt, and arises from the habit of the people of giving to a date the name of the locality from which it is brought, as "Wahi" for any date from the oases, "Yemeny" for dates from the Yemen district of Arabia, etc.

In the shipment of date offshoots received by Mr. Fairchild in 1901, through Mr. Em. C. Zervudachi, of Alexandria, one lot, given the S. P. I. No. 7632, was labeled "Oga de Bedrichen" and in some of the lists this name became transformed into "Oga de Bedreschen." Two trees under the above number and one received without a label were recognized by the writer as identical, and careful notes were made of the leaf and fruit characters, all of which were strongly marked and characteristic.

As no such name occurred in any of the published lists of Egyptian dates, there was naturally considerable interest in the true identity of so conspicuous a variety. Consequently, on arriving in Egypt one of the writer's earliest excursions from Cairo was to the native village of Bedrashen (variant spellings, "Badrashen" and "Badreshen"), a prominent date growing and shipping point on the west bank of the Nile, about 10 miles above Cairo. It is the stopping point for excursionists to the historic site of ancient Memphis and Sakkara, and perhaps no spot in the Nile Valley has witnessed more of the glory of ancient Egypt than this. At the present time there are no more magnificent date groves to be found in Egypt than those that surround this town, Hauamdiye, and a number of other villages between Bedrashen and Gizeh. The soil is a rich sandy loam, capable of producing heavy crops of general produce, and maize is frequently grown beneath the date trees (Pl. III, fig. 2). Going out among the date growers and inquiring for a variety named Oga de Bedrashen, brought the unvarying response that they knew of no such variety. They had only Siwah and Amhat, a few Hamrawi, and some "balady," their name for dates of local origin, or seedlings. On looking over their gardens the young trees of the Siwah had a familiar appearance, and a later visit gave time for the study of the leaf and fruiting characters in detail. Only one conclusion could be reached—the variety we had received under the name of "Oga de Bedrichen" is no other than the Siwah, the leading variety of the Bedrashen and Hauamdiye district and the chief packing date of Upper Egypt. The mudirich of Gizeh has 435,000 taxed date trees, and at a rough estimate 100,000 of them are of the Siwah variety. With the exception of a few trees that are being planted in Fayum, there seems to be little known of this variety outside of Gizeh Province, and within that it is chiefly confined to the section south of Gizeh station and to a district on the west side of the valley and north of the pyramids. Of its origin or the date of its introduction into this district, nothing could be learned. The name at once suggested an introduction from the oasis of that

name. But unlike Dongola Province, where they preserve a distinct tradition of having obtained their date varieties from the Sukkot country, these people have no record of the introduction of the Siwah into their country, and they insist that it originated there.

The situation is further complicated by the fact that there is an exceedingly close resemblance between the Siwah and the Saidy, the great export date common to the entire chain of oases of Western Egypt, from Siwah at the northwest, to Baharieh, Farafreh, Dakhleh, and around to Khargeh. A most careful comparison of all the characters of trunk, leaf, and fruiting stalk fails to show points of constant difference between these varieties, unless it is in the thickness of the fruiting stalk, which, on the whole, seems to be lighter in weight in the Saidy than in the Siwah. How growing in the same soil conditions would affect them in this respect can only be determined by trial. The fruits are so closely related in character that the oasis Saidy variety, as packed and brought to the Nile Valley, shows no constant differences that will distinguish them from the Siwah of Bedrashen, though individual lots may vary considerably. The question again arises of how the varieties would behave if grown side by side, in identical soil conditions. The rich soil of Bedrashen and Hauamdiyah might produce somewhat different results in a variety than would be produced in the rather poor, sandy soils of Khargeh and Dakhleh Oases, in which the writer studied the Saidy. Trees of "Saydy," S. P. I. No. 11485, fruited in 1912 in a very sandy soil at the Mecca Date Garden in California, and were considered by Mr. Bruce Drummond, in charge of the Indio and Mecca Date Gardens, to be identical with the "Oga de Bedrichen" (Siwah) of Tempe. The writer at first concurred in this opinion, but with a more detailed examination of the Mecca plants concluded that they were distinct. After seeing both varieties, as grown in Egypt, to still regard them as distinct, with so many points of identity, can only be accounted for in one way. The Siwah, from its narrow dissemination, is possibly the younger variety and a seedling springing from the Saidy, the fruit of which has found its market in the valley for many years. Analogy for an even closer resemblance of a seedling to its parent is found in Mr. James Reed's "Pioneer" seedling of the Deglet Noor, produced at Thermal, Cal.

There is another point that makes it of importance that the Saidy and the Siwah should be tested in identical situations. The ripening of the two varieties is about simultaneous, in spite of the remoteness of the localities and marked difference in the temperature. At Dakhleh the mean temperature for the nine months of the growing period, from flowering to date harvest, February to October, inclusive, is 78.40 °F. That of Heluan, the nearest record point to the Siwah date field, for the same period is 72.54° F., or 5.86 degrees lower. As shown in Table I, the summation of heat units from May to October, inclusive, is 1.079 higher at Dakhleh than at Heluan. These figures, showing so many more available heat units for the Saidy than for the Siwah, would lead us to expect it to ripen earlier, provided the varieties are identical, and they offer the strongest argument presented in support of a varietal difference between the two.

The maximum yield of Siwah at Bedrashen is given as 100 kantars of 320 pounds to the feddan, practically 1 acre, or often only 60 or 70 kantars. The maximum yield would then be 32,000 pounds to the feddan, which, allowing 100 trees to the feddan, would give a yield of 320 pounds to the tree. At 80 piasters per kantar the money return would be £80, or \$400. Placing the yield at 60 kantars, the more probable average, the crop would be 19,200 pounds, or 192 pounds to the tree. At the minimum price of 60 piasters per kantar the return would be £36 to the feddan, or \$180 per acre; 70 kantars, a medium yield reported, would equal 22,400 pounds, or 224 pounds to the tree, a not unreasonable yield. This, at 80 piasters, would give £56, or \$280 to the feddan or acre. This, it should be remembered, is on land valued at the rate of £100 to £200 per feddan.

SULTANY.

(Known only in limited numbers in the Dakhleh Oasis.)

Trees of the Sultany variety are tall with moderately heavy trunks, the ribs being of medium breadth at the base and tapering rather slightly toward the apex. The spine area is about 28 per cent of the blade length, the spines slender and acute, 2 or 3 to 5 or 6 inches long, passing to ribbon pinnæ of three-fourths of an inch broad and 17 to 18 inches long at 4 feet. The greatest length of normal pinnæ, about 22 inches, follow these, but the length of 16 to 20 inches is maintained nearly to the apex, where they drop to a length of only 12 to 16 inches. The greatest breadth of $1\frac{1}{2}$ inches is reached by a portion of the pinnæ at 7 to 10 feet from the base.

These leaves have several remarkable characters, the high number of antrorse pinnæ, more than half of the entire number, being the most striking feature. These are set at very narrow angles of axial divergence and diverge strongly from the plane, giving a narrow valley bordered by strongly antrorse pinnæ that are well placed for defense. The unusually small number of introrse pinnæ stand at angles of 45° to 69° . The retrorse pinnæ form axial angles varying from 30° to 45° , but lie in the blade plane or at slightly dorsal angles. The thickness of the pinnæ varies from 0.018 to 0.021 of an inch. The general color is bluish green, with a heavy waxy coating. The pulvini are large, with some tendency to being caudate, with a few groups coalescent. The fruit stalks are moderately long, the strands (shamrokh) are long, and both are bright orange.

The unripened fruit is a waxy yellow. The mature fruit is oblong, $1\frac{1}{8}$ to 2 inches long, seven-eighths of an inch broad by three-fourths of an inch deep, showing a distinct dorso-ventral flattening, with sides marginate toward the apex. The meeting of the marginal ridge by a slight or decided curve at the abruptly apiculate apex gives an obtuse wedge form, which is a character of this variety. The greater flattening of the ventral face and the curve of the marginal ridge in that direction are sufficiently pronounced to enable one to determine by inspection the dorsal and ventral surfaces of the fruit, as is proved by sectioning and disclosing the seed (Pl. XV).

The surface of this fruit has many small longitudinal furrows united by finer transverse reticulations.

The darker apical portions are colored "bay" or "chestnut" (R. II) with lighter portions from "honey yellow" to "cream buff" (R. XXX). There is a thin "lavender" (R. XXXVI) bloom over all.

The firm, nearly dry flesh is from one-eighth to three-sixteenths of an inch thick. The outer, more sirupy parts are colored like the darker portions exteriorly, the inner layer a "cartridge buff" (R. XXX). The seeds, about $1\frac{1}{4}$ inches long and three-eighths of an inch broad, are a good deal corrugated. They taper slightly toward the base and have a broadly rounded apex. The germ pore is about three-fifths of the seed length from the base, the ventral furrow being broad and shallow.

Beneath the rather closely adhering membranaceous coating the seeds are "fawn color" (R. XL).

In the atmospheric conditions of Washington these fruits run 40 or 42 to the pound; weighed six months after harvest. The seeds constitute about 13 per cent of the gross weight, a ratio which must be expected to run higher in dry dates than in the moist varieties.

This variety is believed by Mr. Brown, Horticulturist of the Egyptian Ministry of Agriculture, to be the true Sultany, though there are one or two other varieties in the Nile Valley which are called by that name. This is only known to occur in Dakhleh Oasis and only eight trees of it are definitely known. Of these, all but one have passed the offshoot-bearing stage. The eighth tree proved to be a "thirsty" one, located on a ditch from a failing well. This had two or three grown "daughters," on one of which were two small offshoots of a size to move and several which were too small

to disturb. A contract was made for the regular watering of this tree by hand and a price agreed upon for the offshoots as they become large enough to remove. Owners of trees of this variety keep their fruits to set before guests or to send as presents. It could not be learned that they had ever been grown in commercial quantities. The fruit of this variety will take first rank in the dry-date class.

TAMR.

A third-rate date found in considerable numbers in Khargeh and Dakhleh Oases. Its chief interest lies in the fact that it bears some resemblance to the Saidy and that it is mixed with the inferior grades of the latter variety and sold to the Bedouin traders at low prices for consumption by the poorer people. While hardly to be classed as a dry date, it may pass as semidry.

The fruits are about $1\frac{3}{8}$ inches in length and three-fourths to seven-eighths of an inch in diameter, with square blocky base, oblong form, and broad, abruptly rounded apex. They are sparsely and rather coarsely wrinkled and reticulate, but with more of smooth surface than is usual (Pl. XVI).

In color the brighter parts are "mahogany red" or "chestnut" (R. II) or more often near to "russet" (R. XV), with lighter basal portions "tawny olive" (R. XXIX) or clay color. The rather dry flesh is sweet, without richness or characteristic flavor. The seeds might aptly be called moccasin shaped. They are flattened, about seven-eighths of an inch long, three-eighths or seven-sixteenths of an inch broad at one-third the length from the broadly rounded apex, and taper from this point to a rather broad base. The ventral furrow is broad, rather shallow, and corrugated, the germ pore being nearly central. Inside the closely adhering membranaceous coating the seeds are colored a dark "wood brown" (R. XL).

ZAGLOUL.¹

(Notes from Gizeh Garden, Cairo, Nov. 12, 1913.)

Except for a few trees in the older palace gardens around Cairo, including those from which these notes were taken, the culture of the Zagloul variety is confined to the cool regions of the Mediterranean coast, the greatest number of trees being found around Rosetta and Edku, but the fruit is produced in considerable quantities around Ramleh and Alexandria.

The trees are very tall, but more slender than those of Samany, and the crowns are not as spreading. The leaves are 11 to 12 feet long, the rib rather light, small, and inclined to be flattened at the base, but tapering rather slowly toward the apex, so that its curving is stiff, rather than graceful.

The spine area is very short, only 15 to 18 inches, the spines $1\frac{1}{2}$ to 6 inches long, slender, weak and acute, usually placed singly.

The pinnae in the lower part of the blade range from 18 to 26 inches in length, 22 to 25 inches long through the middle of the blade, and diminish to 12 or 15 inches at the apex. They are rather narrow, not more than an inch broad in the lower portion of the blade, and not exceeding $1\frac{1}{2}$ inches in the middle portion; smooth, rather soft, and seldom acute.

The paired groups are greatly in the majority, and quadruple groups are infrequent. The pulvini are inconspicuous and none are caudate or coalescent. The fruitstalks are short, heavy, erect or but little outcurved, the strands (shamrokh) being of medium length, rather coarse.

The fruits are $2\frac{3}{8}$ to $2\frac{3}{4}$ inches long and $1\frac{1}{4}$ inches broad, usually oblique and unsymmetrical, the broadest portion about three-fifths of the distance from the base, from

¹ This is the name of an Egyptian family. It is stated that one Zagloul was the ruler of the Rashid country many years ago and that this date was named for him.

which it rounds unequally to an obtuse apex (fig. 9). The brilliant and striking color of this fruit is rather elusive when one tries to place it. In some specimens a deep "pomegranate purple" (R. XII) is the most apt description, while others are better described as "carmine," deepening to "ox-blood red" (R. I). Either on the trees or in the market stalls this date has the most attractive appearance of any Egyptian variety. The skin is thin, and as the fruit ripens it easily slips from the flesh. In the condition usually marketed the flesh, about three-eighths of an inch thick, is crisp, brittle, juicy, sugary sweet, with but a slight astringency. Its color is best described as "maize yellow" (R. IV), but with a zone on the outside of about 2 mm. thickness of a deeper tint. The seeds are large, irregular oblong, roughly corrugated, and usually imperfectly filled out at the base, the germ pore central, the ventral furrow irregular, but usually shallow and open. The darker parts of the seed are colored "tawny olive" (R. XXIX), shading to "olive-buff" (R. XL).

The fruits of the trees in the Gizeh Garden were "ripe," that is, marketable, the first week in November. The variety did not appear on the market from the coast region till about November 17. From that time until the middle of December there was a steady shipment, but they did not remain on the market as late as the Samany. It is stated

that a few of both this variety and the Samany come to the Alexandria market from the cooler spots up the coast nearly throughout the winter.

Doctor Eisen's paragraph relating to S. P. I. No. 32327, must be based on a good deal of misinformation, both as to locality and time of ripening. This variety does not occur in the Fayum at all, and the few trees in Cairo gardens cut no figure commercially.

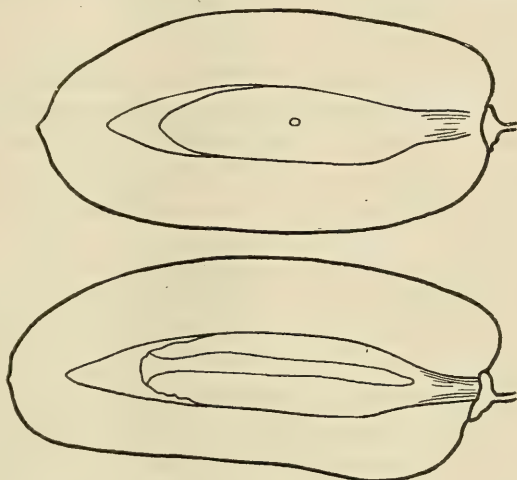


FIG. 9.—Outlines of the Zagloul date, two variations, in "rutab" (fresh) condition, on the Cairo market, November, 1913; shipped from EGku, on the Mediterranean coast. (Natural size.)

SUMMARY.

Date culture in Egypt and the Sudan is of very ancient origin, extending far back of the Christian era. The present number of date trees in these countries approximates 9,000,000, with an annual product valued at about \$1 per tree. Of these trees, not to exceed one-fourth are of 12 important commercial varieties, the remainder chiefly "balady," or seedling, trees producing fruits of inferior grade commanding low prices.

Date culture in the Nile Valley extends with little interruption from the Mediterranean coast to Khartum, a distance of about 1,100 miles, the longest continuous north and south extent of date culture in the world. This embraces a range in mean annual temperature

of more than 15 degrees and, equally important, a range in the percentage of mean relative humidity varying from 74 per cent at Port Said to only 24 per cent in Dongola Province in the Sudan.

For convenience in study, the region has been divided into three zones, designated as (1) the maritime subtropical, comprising the Nile delta below Cairo; (2) the desert subtropical, comprising the Nile Valley from Cairo to Aswan and the western oases; and (3) the desert tropical, comprising the date-growing sections of the Nile Valley from Aswan to Khartum. The records of 12 Egyptian and Sudan weather stations have been compiled and arranged in a table, showing their bearing on date requirements.

The characteristic date varieties of each zone are grouped to show the influence of these varying climatic conditions and the important facts brought out: (1) That the cool and humid maritime zone produces few packing dates, but almost exclusively those used in the fresh, or "rutab," state; (2) that packing dates of superior quality are produced in the moderately hot and dry portions of the desert subtropical zone; (3) that the hotter, less humid portion of the desert subtropical zone and the desert tropical zone produce almost exclusively the hard, dry, self-cured dates, so easy of storage and transportation and so important a part of the diet of the Arab people.

The correct names of two varieties listed in the early importations from Egypt as "Birket el Haggi" and "Oga de Bedrichen," promising in Arizona and California, were ascertained by visits to their original localities.

The identity of the date of which Mr. David Fairchild purchased the fruit as "Wahi" in Fayum in 1901, with the Saidy, the great packing date of the western oases, was learned on a trip to Khargeh and Dakhleh.

The Ibrimi and Sukkoti varieties of earlier published lists were found to be synonyms of Barakawi, the dry date of greatest commercial importance in the Sudan, probably originating in Sukkot.

Of the 22 varieties of dates described, 14 have not been previously published, and of the remaining 8 the descriptions are more complete and are believed to be more accurate than any heretofore published.

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BULLETIN No. 272

Contribution from the Forest Service
HENRY S. GRAVES, Forester



Washington, D. C.



September 27, 1915

THE SOUTHERN CYPRESS.¹

By WILBUR R. MATTOON, *Forest Examiner.*

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IMPORTANCE.

In the amount of lumber produced in 1913 cypress ranked sixth of the conifers or softwoods. On account of the durability of the heartwood and its moderate softness, which makes it easily worked, cypress is a wood of high intrinsic value. Cypress trees not uncommonly reach an age of over a thousand years, a height of from 120 to 130 feet, and a diameter above the basal swell of from 8 to 10 feet. Cypress is very persistent in growth, and is one of the few conifers which successfully sprouts from the stump.

Cypress is restricted in its natural occurrence to deep, rich swamp lands. The problem of bringing it under forest management is therefore intimately related to that of reclaiming swamp land on an extensive scale by drainage. Though preeminently a tree of the swamp, when planted it thrives in as wide a range of climate and soil as

¹ Southern cypress (*Taxodium distichum* Rich.), of the southeastern United States is known among botanists as "bald" cypress because in contrast to most conifers, which are evergreen, it sheds its leaves annually.

most of our forest trees. Naturally, however, it occurs in commercially important quantities only in regions where logging is difficult and expensive.

Because of its power to develop special organs or parts, cypress possesses unusual ability to adapt itself to conditions of soil and water generally considered extremely unfavorable to tree growth. As a result, the tree occurs in various forms differing quite widely in respect to leaf, bark, shape, size, and to a limited extent, in wood characteristics. In soft, unstable soils and locations subject to periods of high water, cypress develops peculiar knees which appear to serve the double function of organs for breathing and anchorage. Although its home is in unstable soils, the tree is seldom if ever thrown by wind.

Cypress is interesting, botanically, as one of the few surviving members of a race of trees which was prominent in geologic times. Among its associates were the redwoods of California. Only two other close relatives are known, one an evergreen cypress on the tablelands of Mexico and the other a tree occurring in China.

Cypress is readily grown from seed and is well adapted to nursery practice. By many authorities it is considered one of the most beautiful and ornamental trees for park planting, for which it has been used quite widely over the eastern and central portions of the United States. Although cypress has not been raised in forest plantations on a large commercial scale, experience thus far points to the commercial success of forest planting, under certain conditions, in the deeper and fresher soils.

GEOGRAPHICAL AND COMMERCIAL RANGE.

The geographical range of cypress extends from southern New Jersey¹ over the Atlantic coastal plain to Florida, thence south to the extreme southern end of the Florida peninsula,² and westward through the Gulf Coast region nearly to the Mexican border in Texas, and up the central Mississippi Valley to southern Illinois and Indiana. This range covers all of Florida, Mississippi, and Louisiana, the southern half of Georgia, and Alabama, and lesser portions of 11 other States. Locally, cypress is confined strictly to river and interior swamps, wet depressions, and stream banks.

The commercial range of cypress is much more restricted than the botanical range. The district of heavy commercial stands centers in the lower Mississippi Valley and Florida, where deep swamps abound. The large coastal river and isolated inland swamp districts are regions of important commercial production. These in-

¹ Shaler, Dr. N. S., *Memoirs of the Museum of Comparative Zoology*, Harvard University, Vol. XVI No. 1, p. 11; also Witmer Stone, "Plants of Southern New Jersey," *Report of New Jersey State Museum for 1910*, p. 151.

² Harper, Roland M.

clude the Lumber River and the Wilmington swamps (North Carolina), Peedee, Santee, and Salkehatchie Rivers (South Carolina), Okefinokee Swamp and Flint River (Georgia), Suwanee and Apalachicola Rivers and parts of the Florida peninsula, and the alluvial flood plain of the Mississippi, at scattering points below the St. Francis Basin in Missouri, but preeminently over the broad, deep swamp area south of Baton Rouge in Louisiana.

The introduction of larger and more efficient logging machinery has advanced the logging in any specified region from the water

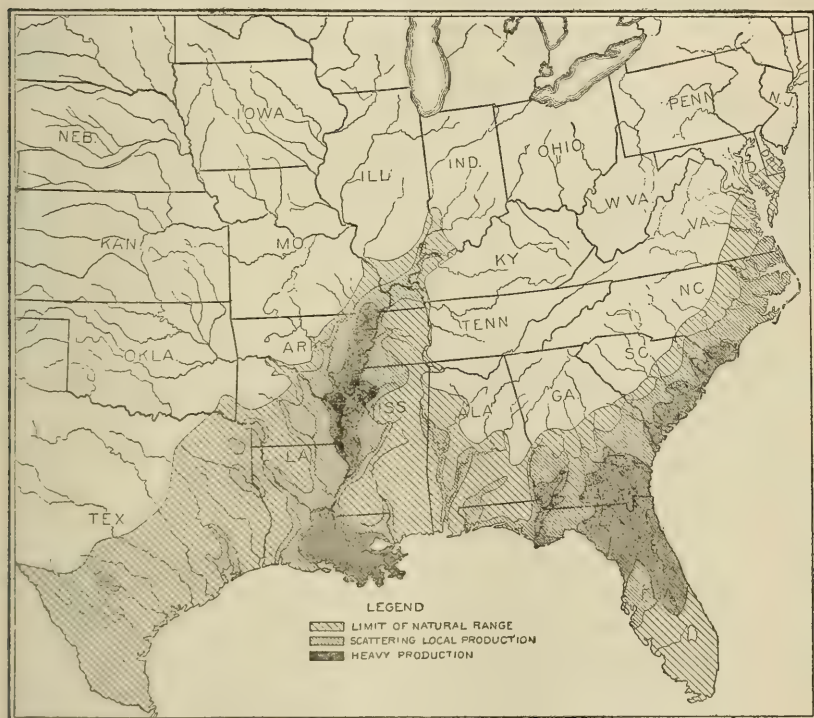


FIG 1.—Geographical and commercial distribution of cypress in the United States.

fronts into the deeper and less accessible swamp areas. Thus, the evolution in logging methods chiefly accounts for the continued commercial importance of cypress in regions where lumbering was actively in progress many years ago.

PRESENT SUPPLY AND ANNUAL CUT.

STANDING TIMBER.

The total present stand of cypress, according to the best available estimates, is about 40,000,000,000 board feet, of which about 1,000,000,000 feet are being cut annually.

The general inaccessibility of swamps and the difficulty of cruising by ordinary methods have probably strengthened in the case of cypress the general tendency to underestimate timber. Successive estimates of the total stand have constantly increased, in spite of the heavy annual cut. In 1897 an investigation placed the amount of standing cypress at 33,000,000,000 feet.¹ In 1909, however, the Bureau of Corporations estimated the amount of standing cypress at 40,000,000,000 feet, distributed by States as shown in Table 1.

TABLE 1.—*Total estimated amount of standing cypress, by States.*¹

State.	Total stand.	Per cent of total stand.
	<i>Board feet.</i>	
Louisiana.....	15,700,000,000	38.9
Florida.....	10,700,000,000	26.5
North Carolina.....	3,000,000,000	7.4
Georgia.....	2,800,000,000	6.9
South Carolina.....	2,600,000,000	6.4
Arkansas.....	2,200,000,000	5.5
Mississippi.....	1,900,000,000	4.7
Missouri.....	900,000,000	2.2
Alabama.....	200,000,000	.5
Virginia.....	200,000,000	.5
Texas.....	200,000,000	.5
Total.....	40,400,000,000	100.0

¹ Department of Labor, Bureau of Corporations, "The Lumber Industry, Part I, Standing Timber," p. 76. To these figures, which represent the stand privately owned in all States, should be added a small amount of State and Federal timber and private timber in Maryland, Tennessee, and Kentucky.

Thus, Louisiana was credited with nearly 40 per cent and Florida with more than one-quarter of all the standing cypress.

Stands of second growth are becoming merchantable, and may now be included. The Louisiana Conservation Commission in its report for 1914 estimates the present cypress stand of that State at 14,130,000,000 feet. This is only 570,000,000 feet less than was given by the estimate of 1909 quoted above, yet Louisiana in 1912 alone cut over 653,000,000 feet, and has been cutting at about the same rate annually during the five years since 1909. Owners are invariably cautious about giving out information regarding the amounts of timber in their holdings. This situation and the factor of annual growth being taken into account, the total stand of cypress in 1914 is believed to be not less than 40,000,000,000 feet.

ANNUAL CUT.

The total cut of cypress lumber in 1913, exclusive of lath and shingles, was 1,097,247,000 board feet.² Since shingles and lath are made from the slabs and other kinds of "mill waste," and poles and ties are usually cut from small sizes not considered in the original

¹ Mohr, Dr. Charles, Report for the Forest Service, U. S. Department of Agriculture.

² The Bureau of Crop Estimates, in cooperation with the Forest Service, U. S. Department of Agriculture, based upon reports of 607 mills. Reports from mills cutting less than 50,000 feet not included.

estimates, the relation of cut to the total standing timber is unaffected by the lack of any figures for these smaller products. On the basis of the estimate given above, the present annual cut amounts to about 2.7 per cent of the standing timber. During the decade following 1899 the annual cut practically doubled (92.7 per cent increase), rising from a little less than 500,000,000 feet to 955,635,000 board feet. Table 2 shows the cut of the various States in 1913.

TABLE 2.—*Quantity of cypress lumber sawed in 1913 and in 1909.*

State.	1913			1909		
	Quantity.	Per cent of total.	Active mills reporting.	Quantity.	Per cent of total.	Active mills reporting.
	<i>Board feet.</i>			<i>Board feet.</i>		
Louisiana.....	744,581,000	67.9	94	608,854,000	63.7	153
Florida.....	100,723,000	9.2	41	84,811,000	8.9	85
Georgia.....	74,818,000	6.8	57	27,517,000	2.9	84
South Carolina.....	39,895,000	3.6	43	36,040,000	3.8	55
Arkansas.....	35,964,000	3.3	98	55,012,000	5.7	309
Missouri.....	28,814,000	2.6	49	32,819,000	3.4	125
Mississippi.....	25,782,000	2.3	54	41,666,000	4.4	209
North Carolina.....	19,213,000	1.8	62	34,506,000	3.6	150
Tennessee.....	14,502,000	1.3	44	8,709,000	0.9	73
All others ¹	12,955,000	1.2	65	25,629,000	2.7	261
Total.....	1,097,247,000	100.0	607	955,635,000	100.0	1,504

¹ Includes mills in Maryland, Virginia, Alabama, Texas, Indiana, Illinois, and Kentucky.

For all the States the average production per mill in 1912 exceeded a million board feet, in Louisiana it was 5,785,000 board feet.¹ This is exceeded only in the manufacture of Douglas fir, redwood, and southern yellow pine. In Louisiana, the average cut per mill in 1909 was 3,900,000 feet for 153 mills; in 1912, nearly 5,800,000 feet for 113 mills; in 1913,² 7,900,000 feet for 94 mills. In the whole region though the total cut reported increased about 15 per cent, the total number of mills reported dropped from 1,504 in 1909 to 607 in 1913, a reduction of about 59 per cent.²

In 1913 for the first time the annual cut reached 1,000,000,000 feet, over 100,000,000 more than the 1912 cut, the highest reported up to that time. The number of active mills reporting in 1913, however, was 372 less than in 1912. Increases in cut over 1912 were large on the Atlantic coast, in South Carolina and Georgia,³ and in the Mississippi basin in Louisiana, Mississippi, and Tennessee. In the five years ending in 1913, the annual cut very nearly tripled in size in Georgia, increased 25 per cent in Florida, and 67 per cent in Tennessee. Decreases of 44 per cent in North Carolina and 53 per cent in Arkansas occurred in the same period.

¹ 1,018,000 board feet, as compared with 635,400 board feet in 1909.

² Mill cutting less than 50,000 feet of lumber annually not included in 1913 statistics; 1909 figures from complete decennial census.

³ Partly because of the opening up of the Okefinokee Swamp.

PHYSICAL AND MECHANICAL PROPERTIES OF THE WOOD.

Cypress wood is strong and stiff, moderate in weight and hardness, and very moderately subject to shrinkage. It is usually fine-grained, light to dark brown in color, and durable under trying conditions of moisture. The wood is easily worked.

COLOR.

Cypress averages darker in color in the Gulf and South Atlantic region, and correspondingly lighter as one passes northward up the Mississippi and Atlantic coast. In any specified locality, however, wide color variations occur, although usually one color predominates. For example, the cypress of the deep St. Johns River swamps, Florida, averages an amber or light orange-brown, and is referred to under the trade name of "yellow" cypress. Nearby, in shallower isolated swamps of different soil and moisture conditions, the wood is decidedly darker, with a more pronounced grain when sawed. Along the lower Apalachicola River and in similar deep alluvial river plains, the prevailing orange-brown of the heartwood is occasionally varied to the deepest brown or chocolate color, often streaked on a lighter background. This wood is very handsome in its color markings and mottling. Much of the lumber from the lower Mississippi delta and other southern regions shows prominently the harder and darker reddish colored bands of the heavier summerwood in each annual ring, and has come to be known commercially as "red" cypress. The annual rings of cypress and a marked irregularity of growth give to the wood a richly grained effect, for which it is widely sought for interior finish.

The wood from both of the northern regions is spoken of in the market as "white cypress." In logging, this term means that the wood floats high. Along the Atlantic coast "black" cypress refers to heavy wood which sinks, or floats very low if at all. In the Gulf regions "black" cypress refers more especially to distinctions in color rather than buoyancy, since in respect to weight dark wood is often not noticeably heavier than the lighter shades. The cause for variations in color can not now be completely pointed out.

WEIGHT.

The wood varies in weight usually from 22 to 37 pounds, averaging about 28 pounds per cubic foot, when thoroughly air-dried. The equivalent specific gravity is 0.35 to 0.60, averaging about 0.45. Cypress wood ranges about midway between the white and the hard yellow pines. It is a little lighter than eastern red cedar, but considerably heavier than redwood, western red cedar, eastern spruce, and eastern white cedar. Green or unseasoned cypress varies in

weight from about 50 pounds per cubic foot to more than 62.35 pounds, the weight of an equal amount of water.

In a series of tests the Forest Service¹ found that cypress wood taken from all parts of the individual tree was strikingly uniform in weight, structure of rings, and strength.

As a rule the wood of cypress growing in ponds and other swamps with acid soils averages much heavier than that of the typical form growing along fresh, active streams. The wood from six representative trees growing in strongly acid pond soils in South Carolina averaged 0.50 in specific gravity² as compared with 0.44³ specific gravity for four typical river cypresses from the fresh water of the Savannah River bottom in the same region. The heaviest wood (specific gravity 0.55) in 39 representative trees taken from four southern States was in a tree growing very slowly in a pine-barren pond in South Carolina. In the Dead Lakes of western Florida, where an extensive cypress forest has been gradually inundated, very slow growth in fresh, clear water produced soft, light-weight wood. In swell butts, knees, and large roots, where growth is rapid, the wood is very much below the average in weight. The lightest of this wood is used to a limited extent as a substitute for cork, especially for making fish-net floats and the like. One piece showed a specific gravity under test of 0.19, or only 10 pounds per cubic foot, which is considerably lighter than cork. During several months in the year the water in the great overflow belt along the Mississippi becomes increasingly stagnant and charged with humus compounds in solution, resulting in moderately unfavorable conditions for growth. This region produces much of the characteristic darker colored "red" cypress of good average weight and strength.

STRENGTH.

In respect to strength cypress holds a position intermediate between that of the white and the heavy yellow pines. The close relation between weight and strength both in compression and cross-bending, as shown by tests on cypress in a green state, is set out in Table 3.

¹ Forest Service Circular 19, "Progress in Timber Physics: Bald Cypress," by Filibert Roth, p. 22.

² Ranging from 0.42 to 0.58.

³ Ranging from 0.39 to 0.48.

TABLE 3.—Average strength values of green cypress in compression endwise and in bending for pieces of different weight.¹

Wood (air-dry).		Compression parallel to grain (crushing strength at maximum load, per square inch).	Bending.	
Specific gravity.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
0.58	36.2	6,500	6,800	7,800
.54	33.7	4,800	5,600	7,100
.50	31.2	4,700	5,000	6,300
.44	27.5	4,200		
.41	25.6	3,800	4,500	5,800
.37	23.1	3,200	3,800	5,100
.35	21.9	2,900	3,600	5,000

¹ Forest Service Circular 19. Strength tests on cypress have not yet been made at the Forest Products Laboratory in connection with the series for commercial woods of the United States, and the figures given in Tables 3 and 4 can not be compared with those for other kinds of wood so far obtained in the latter series, since conditions of test were different.

In the above tests the varying strength values of green cypress are shown to be correlated pretty closely with the varying weights and densities of the wood. Trees on adjacent but dissimilar sites are known to produce wood differing markedly in strength. The first test was with a small cypress over four centuries old, grown in a "pond" in South Carolina, which proved to be the heaviest and likewise the strongest and stiffest timber tested.

Similar tests made with air-dry wood (12 per cent moisture) from 16 cypress trees selected from various portions of the range show, in Table 3, the variation in strength values and their general correlation with weight.

TABLE 4.—Average strength values of air-dry (12 per cent moisture) cypress.¹

Wood (air-dry).		Average strength in pounds per square inch.			
Specific gravity.	Weight per cubic foot.	Compression parallel to grain (crushing strength at elastic limit, per square inch).	Bending.		
			Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>1,000 lbs.</i>
0.58	36.2	7,860	9,000	8,480	1,774
.55	34.4	6,510	6,920	8,120	1,355
.52	32.5	7,290	8,730	11,350	1,734
.51	31.9	6,270	6,490	7,540	1,173
.50	31.2	6,100	6,470	8,160	1,173
.49	30.6	7,660	8,380	9,710	1,786
.48	30.0	7,170	7,770	9,350	1,275
.47	29.4	6,890	7,230	8,880	1,163
.46	28.8	7,740	7,670	10,370	1,768
.45	28.1	6,070	6,550	8,180	1,406
.44	27.5	6,760	7,710	8,900	1,660
.43	26.9	5,470	5,000	6,240	892
.42	26.2	5,520	5,990	7,030	1,075
.39	24.4	5,200	4,900	5,750	841
.37	23.1	4,770	5,120	6,210	996
.35	21.9	6,070	6,550	6,250	925

¹ Forest Service Circular 19.

DURABILITY.

The great durability of the heartwood, probably more than any other property, gives cypress the place of distinction which it holds among the more valuable woods on the market. In contact with the soil or exposed freely to water or atmospheric conditions the heartwood ordinarily resists for many years the agencies of decay, while the sapwood under the same conditions is comparatively short-lived. Instances of cypress shingles¹ lasting 50 to 100 years, fences in good condition after 40 years, old plantation buildings in the warm, humid Southern States in excellent preservation after 100 to 200 years,² and others of a like character are frequently reported.

As the result of tests under way the Forest Service will be able later to furnish information in regard to whatever relationship may exist between color, oil content, and durability. The amount of oil or resin content in the wood varies considerably and is judged by the soapy feeling, which is somewhat characteristic and aids in identifying cypress. The name "cypressene" has been applied by some to this resin.

Cypress, like most other woods, is not entirely uniform in respect to durability. In fence lines some posts have to be replaced sooner than others; in boats some planks decay while others last almost indefinitely. In old cuttings the flat tops of large stumps are observed to vary in soundness although of exactly the same age. The seasoned heartwood when exposed to the weather appears to wear out by the mechanical action of water and atmosphere before it gives way through decay. Pecky cypress, although mechanically weaker than sound cypress in proportion to its bulk or mass, is very durable. The fungus producing the pecky wood is not known to cause any further injury after the tree is cut.

MOISTURE AND SEASONING.

The water content of living cypress is variable, and in the lower part of the trunk quite large in amount. Green cypress logs are nearly double the weight of air-seasoned wood. In logging operations trees are girdled in advance of felling in order to increase their buoyancy. (See p. 12.) The prevailing belief is that green cypress contains more water and dries at a slower rate than other kinds of "softwoods." Experience has shown that cypress is a rather difficult wood to season, both in the air and in the dry kiln, with a tendency to caseharden in the latter method. Preliminary experiments indicate that, in kiln drying, cypress requires a length of time more nearly like the hardwoods than the conifers. There is little doubt that cypress wood can be successfully dried when properly handled.

¹ The split or riven shingle known variously as "boards," "shakes," "shingles," etc.

² Mulberry Castle, on the Cooper River, S. C., built in 1714.

At present, however, purchasers largely specify against dry-kiln and in favor of long-period air-seasoned lumber.

Cypress shrinks about 8 to 10 per cent in volume,¹ and in this respect is intermediate between the light and heavy pines.

USES.

Cypress has a great variety of uses, and for many of these it is selected as a preferred material. The key to its usefulness is its resistance to decay and other forms of deterioration when in contact with moisture, and its quality of being easily worked. It is used extensively for outside finish of buildings, such as siding, casing, sashes, doors and blinds, cornice, railings, steps and porch material. As a gutter stock, cypress outlasts many other materials and is in favor for high-grade work. Standard planing products consume large quantities of cypress. These include ceiling, siding, flooring, molding, and finish. On account of its freedom from taste and great durability it is a preferred material for tanks, vats, tubs, and wooden buckets. These are used for water storage, and by creameries, breweries, bakeries, dye works, distilleries, and soap and starch factories. In the construction of greenhouses, where wood is subjected to extremes of heat and moisture, cypress is used probably more than any other wood. It is also a leading wood for pumps, laundry appliances, caskets, and coffins. Cypress is extensively used throughout the South in the construction of picket fences, which there remain the standard form of yard fence. In the moist, hot climate of the South, split cypress shingles have outlasted all other roofing materials commonly used, except the best grade of slate and tiles. While the ordinary sawed shingle is very durable, the relatively high value of cypress wood has resulted in cedar taking the lead as shingle material.

More than two-thirds of the total cypress-lumber output, estimated in round figures at 740,000,000 board feet in 1914, is further manufactured and utilized by the wood-manufacturing industries in the United States. The reports for 1911 show that 68 per cent (668,353,342 board feet) of the amount cut in that year was so used by these industries.² The balance of the lumber cut goes into general use in the retail market.

Relatively small amounts of cypress go into the primary products other than lumber. In 1911 the electric and steam railroads purchased cypress crossties to the number of approximately 5,800,000 or about 4.3 per cent of the total for the year.³ Only 72,995 cypress poles were reported purchased in 1911 by all the principal classes of

¹ See Forest Service Circular 19, pp. 10-11, for earlier experiments in drying cypress wood.

² Taking the year 1911 as an average year for figures collected from the wood-using industries in the period 1910 to 1912, inclusive.

³ Includes large numbers of ties from pecky hearts and hewed small-pole timber. Figures for 1911 are latest available for ties, poles, and cooperage.

pole consumers. Small amounts go into cross arms. A little is used for slack cooperage, and, experimentally, cypress has been found to be a substitute for white oak for wine barrels.

Large quantities of pecky cypress, which is relatively cheap, are used where good appearance and water-tightness are not required.

CYPRESS LUMBERING.

Most of the early centers of cypress lumbering were located near the mouths of the larger southern rivers. This was due to the prevailing method of float logging during high water. Logging centers have since moved inland, to the great interior swamps and higher portions of the river swamps.

In the early days large amounts of the finest cypress were annually cut in trespass and floated away. Standing timber was considered of so little value that State authorities and, to a less extent, private owners made little attempt to stop illegal cutting. Under the swamp-land act of September 28, 1850, very much of the swamp and delta lands early passed into the hands of the various States. Later these lands were sold very cheaply to railroads, timber companies, and settlers, in order to encourage the development of the country. The cypress industry has gradually become concentrated in a few hands.

Methods of logging and general mill equipment are essentially similar throughout the South. Various hardwoods, including tupelo gum as the latest addition, are now manufactured to a considerable extent by the cypress mills. Many large mills, however, are cutting only cypress.

LOGGING.

The present logging of cypress is attended by difficulties of a kind unknown in handling any other commercial timber. The bulk of all cypress is now logged by massive steam machinery moved from place to place on railroads built into the deepest parts of swamps over soft and treacherous ground. Periods of high water interfere with both the cutting and the moving of logs. For many years only the timber accessible to streams subject to flooding was taken. The soft nature of the soil and the great weight of the logs made it impossible to move the timber by the usual method—with oxen or mules. The wealth of cypress remained practically untouched until late in the eighties, although a few mills were operating earlier. The decline of the eastern white-pine industry sent into the South lumbermen who solved the difficult problem of logging cypress. Logging progressed from the float method in the eighties to the pull boat in the nineties, and from that to overhead-cableway skidding, the method now in use. (See Pl. I.)

Float logging consists of floating logs during periods of high water through "trails" and "float roads" previously opened in the forest.

The trees are girdled several months in advance of logging. The pull boat, as finally developed, with its stationary engine mounted on a float or barge, skids the cypress over the soft surface for distances up to 2,000 feet or more on either side of the canal or bayou. The dredge boat, working just in advance of the pull boat in digging canals in the swamp soils, gave access to the cypress where natural channels were lacking. The advent of railroad swamp logging with the overhead cableway skidder was the principal factor in opening up vast regions of cypress previously considered inaccessible because not sufficiently inundated. The light skidding engine, mounted on runners and pulling itself over the flat pine woods along the margin of swamps and known as a "snaker," has been a valuable accessory, especially in the Atlantic coastal region.

In the overhead-skidder method the logs are brought in by a carriage or "bicycle" traveling over a powerful cable suspended between the "head tree" and "tail tree," usually 600 feet apart (Pl. I). In the heavier types, such as the duplex-spar skidder, the total distance covered is 2,000 feet in the two opposite directions from the skidder engine, which rests temporarily on piles driven beside the railroad track. The logs are pulled up to the main cableway for distances of as much as 100 feet on either side. Thus a strip 2,000 feet by 200 feet wide, or approximately 9 acres, is covered at each "set." The smaller overhead steam skidder logs at each "set" successively a dozen or more strips 600 feet long extending outward as radii from the engine at the center, covering an area of about 26 acres.

The cost of logging is discussed on page 15 in connection with the total cost of lumber production.

GIRDLING.

It is the general practice to girdle or "belt" cypress trees from 6 months to a year in advance of logging. The result is that about 95 per cent of the logs will float instead of 10 to 20 per cent. This reduction in the number of "sinkers" is a matter of the greatest significance in cheap water logging and pond storage at the mill. Large operators, having considerable amounts of the more valuable hardwoods in mixture, generally use dry log yards instead of log ponds at their mills. In this case the cypress is not girdled.

Under direction of a foreman, girdling crews composed of 2 to 6 men each girdle the trees for a price per tree, usually from 6 to 9 cents, determined in advance by the general size and density of the timber. In order to secure early drying it is necessary in girdling to cut through the sapwood to the heart.

Among operators much variation prevails in respect to the season of the year chosen for girdling and the length of time before cutting. The majority prefer to girdle in the fall because the trees' activities



FIG. 1.—MATURE CYPRESS, 128 FEET HIGH BY 46 INCHES IN DIAMETER, SHOWING CLEAN TRUNK AND FORM OF MATURE CROWN. (GEORGIA.)

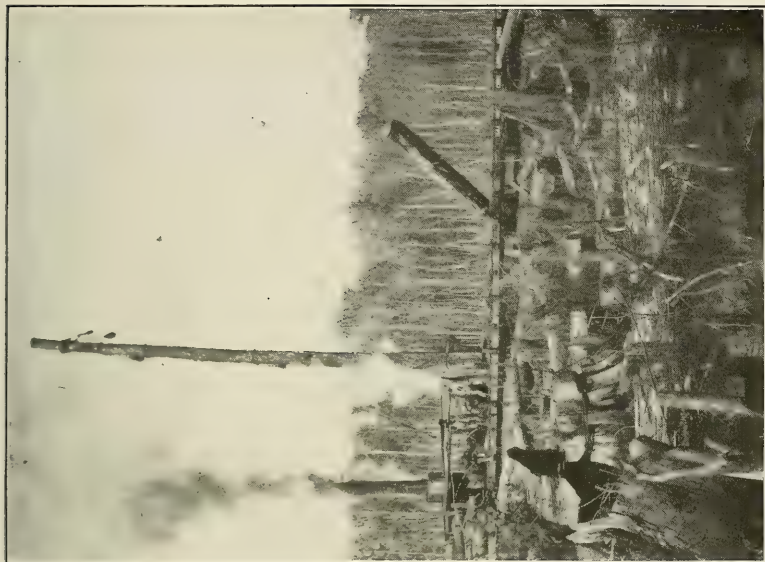


FIG. 2.—LOGGING IN DEEP SWAMP WITH OVERHEAD CABLEWAY SKIDDER AND RAILROAD. (LOUISIANA.)



FIG. 1.—DREDGE BOAT IN CLOSELY LOGGED CYPRESS. NO SEED TREES LEFT AMONG THE MASS OF HEAVY STUMPS AND ROOTS. (LOUISIANA.)



FIG. 2.—WASTEFUL LOGGING BY LEAVING VERY LARGE TOPS AND OFTEN HIGH STUMPS. SEED TREES, HOWEVER, WERE LEFT. (GEORGIA.)

TWO METHODS OF LOGGING CYPRESS.

are then at a low point and because that season is usually the driest in the swamps. Some choose the period following the spring high-water stage. An important influencing factor is the danger of attack by the pinhole borer or ambrosia beetle. For a discussion of this subject, based upon extensive investigations conducted by specialists, the reader is referred to Circular 82, "Pinhole Injury to Girdled Cypress in the South Atlantic and Gulf States," and Circular 128, "Insect Injuries to Forest Products," issued by the Bureau of Entomology, United States Department of Agriculture.

WASTE IN LOGGING.

Various forms of waste in logging are found in some regions. Utilization is complete, however, in the most literal sense of the term, among the Mississippi River operators; as a rule not a living cypress tree is left, stumps are cut low, and top logs are taken. Where clean cutting is practiced trees above 16 to 18 inches at the stump are taken for lumber; from 8 to 14 inches for ties, piling, etc.; and practically everything left by the axe is broken by the steam logger. Over the Atlantic region the wood in the trees felled has in the past been utilized much less thoroughly, and the smaller sized trees left standing. One company in western Florida commendably adheres to a high diameter limit in the selection of trees for felling, but wastefully cuts high stumps and leaves large top logs. As thousands of deadhead logs, or "sinkers," left 10 to 20 years ago, are now being taken out by machinery, so in turn later cutters on the same areas will undoubtedly pick up many large top logs and material left in high stumps. Although present cutting may be for special sizes and grades of stock, it is doubtful if it is wise or practical thus to leave large quantities of good timber in the woods (Pl. II). The high stumps often result from sawyers working in the girdle line, which, of course, is chopped out by the girdlers at as high a point as possible above the basal swell in order to avoid unnecessary labor.

Waste in logging cypress is generally attributed to the poor quality of labor, but is usually due to carelessness in supervision and failure to realize the true stumpage value of the material left. Operators on the Atlantic coast, where freight rates to the larger markets are considerably lower, should be able to apply to their own logging the methods which have been worked out so successfully in Louisiana. In many cuttings in the Atlantic coast region stumps are left 5 to 9 feet high in order to effect a slight saving in labor; while in Louisiana, as a general practice, small trees are cut at 2 feet, and all others, up to the largest sizes, at 3 feet. The amount of merchantable lumber contained in the upper 2-foot section of a stump 4 feet in diameter cut 5 feet in height, allowing 35 per cent for defect and not including the slab, is 90 board feet. At a stumpage rate of \$8 per thousand

feet, the value of the short-log section left is \$0.64, or about 15 cents more than is paid on an average for felling and cutting the trees where the cypress runs good size. The wood left in a similar stump 3 feet in diameter at the top gives a waste of about 33 cents per tree. If operators would spend a few minutes in figuring the total value of the timber left in stumps above a 3-foot maximum many would, in all likelihood, revise their system of cutting.

MILLING.

Large-sized mills are the rule in the cypress industry. Many mills average daily runs of from 80,000 to 100,000 board feet. The larger mills in Florida and Louisiana turn out on an average up to 200,000 feet daily, and a few cut as much as 275,000 feet by using two double-cutter band mills and resaws. With the exception of a few inland swamp districts, the majority of cypress mills are located with reference to convenience in the transportation of either logs or lumber, or both, by water. Logs are rafted to the mill through lakes, bayous, and sometimes artificial canals, for distances of from 50 to 125 miles. The typical mill is equipped with a double band saw, shingle and lath mills, up-to-date planing mill, dry kilns, and a lumber yard of unusually large size. Nearly all use pond storage, and many have complete dry-log yard equipment in addition as a provision against irregularities in girdling and logging during extended high-water periods. Ordinary labor is usually paid for by the day, and the more expert by the month or year. In the highest form of organized manufacture the entire manufacturing operation from the standing tree to the loaded car, with a few minor exceptions, is done under contract at a stipulated price per 1,000 feet.

WASTE IN MILLING.

In mill practice, complete utilization is the rule rather than the exception. The products of the ordinary mill are lumber, lath, and shingles, and a great variety of planing-mill products. The refuse burner gets little of the sound timber except small trimmings and sawdust, but a good deal of trash in advanced stages of decay. Because of the large number of standard short lengths and the strong demand, slabs are worked closely for lumber, and the remainder is sent along with the trimmings into the secondary mills, producing shingles, lath, pickets, etc. In younger cypress, where the butt swell is prominent, butt logs furnish a large amount of such material, and all is in excess of the log scale. Pieces down to 4 inches in width by 12 inches in length are utilized for tubs, buckets, washing machines, etc. Planing-mill orders include a great variety of small sizes for special uses in contact with water. There is still opportunity for considerable improvement in the utilization of small-sized waste on the part of many operators in cypress.

COST OF MANUFACTURE.

The investment required in the manufacture of cypress lumber is considerably higher than for most kinds of timber. The essential factor is the high initial cost of logs delivered at the mill. Briefly, the high expense of manufacture is due to:

- (1) The costliness of the equipment required for logging.
- (2) Cypress is mostly cut into 1-inch lumber, and very little goes into dimension stock, as is the case with the southern pines.
- (3) The stock is usually held from 8 months to a year, and sometimes for 2 years, in order to permit of thorough air-seasoning. This entails large holding charges.

On the other hand, cypress forests are in the lowest situations, affording water transportation in many cases for logging and in some cases for shipping lumber. Float logging, the method of the earlier days, was relatively cheap. In Louisiana the timber lies so far from the water fronts and places where artificial canals are practicable that pull-boat logging is said now to average from \$1 to \$3 more per 1,000 board feet than overhead-cableway skidding and swamp railroads. The fire danger, with the necessity of clearing rights of way and of slash disposal, is eliminated in cypress logging.

Logging railroads are built on piling over swamps at costs ranging from \$9,000 to \$12,000 per mile, and sometimes \$15,000 for main lines. Temporary logging spurs on mud piles, cribbing, or sawdust beds cost from \$1,000 to \$2,000 per mile. The usual equipment consists of locomotives and cars, in addition to the combined skidders and loaders for getting the logs from the stump to the car. The climax of logging machinery, the 135-ton duplex spar skidder in use on the Santee River, S. C., and perhaps elsewhere, costs approximately \$28,000 set up and ready for operation. Water logging by steam requires heavy dredge boats for digging canals, pull boats equipped with skidding engines and tons of steel cable, and tow-boats for getting the logs to the mill. Frequently logging is done by a combination of both methods. In order to avoid undesirable shut-downs, the logging capacity of cypress plants is large in relation to the mill capacity.

The cost of manufacturing cypress is subject to very wide variation, due mainly to the different conditions in logging and the varying soundness of the timber. In the older supply regions costs often run nearly double those in the more virgin districts. The figures below will indicate the general range of cost in complete manufacture:

	Cost per 1,000 board feet.
Logging:	
Girdling (price per tree, 8 to 12 cents).....	\$0. 15 to \$0. 20
Cutting (paid by the tree or thousand board feet).....	. 60 . 80
Skidding and loading.....	1. 95 . 2. 90

Logging—Continued.		Cost per 1,000 board feet.	
Railroading.....		\$2. 10 to	\$3. 10
Depreciation and overhead charge.....		. 70	1. 00
		5. 50	8. 00
Milling:			
Sawing.....		1. 95 to	3. 00
Yarding.....		1. 85	2. 50
Depreciation and overhead charge.....		. 95	1. 50
		4. 75	7. 00
Total		10. 25 to	15. 00

The lesser figure for total cost will appear low for smaller operations in scattered cypress along the Atlantic coast, where complete manufacture costs from \$13 to \$16. In the large tracts of the Mississippi delta, with heavy yields per acre on relatively stable soils and large-scale operations, the cost averages from \$9 to \$13 per thousand. Logging is more expensive than milling by from \$1 to \$3, and milling averages from \$5 to \$7 per thousand feet, because of the large amount of defective or pecky material, close utilization, and small sizes run through the mill. In Louisiana, where the larger companies pay for practically every operation of manufacture by the thousand feet, lumber is produced at the lowest average cost.

GRADES.

Cypress is manufactured and handled in the trade under detailed and very satisfactory inspection rules. The grading rules adopted by the Southern Cypress Manufacturers' Association,¹ composed of about 50 producing companies, are in most general use. Their seven major grades and great number of finish grades are well defined and allow of a marked uniformity. Odd as well as even lengths above 4 feet have been for some years standard, with certain limitations as to the proportional amount of odd lengths. The major grades are tank stock, first and second clear, selects, shop (two grades), selected common tank stock, barn or dimension (two grades), cull or peck. The National Hardwood Lumber Association and the Hardwood Manufacturers' Association both use the rules of the Southern Cypress Manufacturers' Association.

At the saw there has been a gradual decline in the average quality of the lumber, due chiefly to logging in situations less favorable for growth, in tracts formerly culled of the best trees, and closer utilization. Records kept continuously for the past 5 or 10 years show a marked decline in the percentage of clears and selects, and corresponding increases in shop, and especially common.

¹ Mr. George E. Watson, Secretary, Hibernia Bank Building, New Orleans, La.

The seven grades of the Southern Cypress Manufacturers' Association give the following averages in a number of representative localities, with 5 to 15 years' cut in the future: Tank, 2 per cent; clears, 15; select, 16; shop, 19; barn, dimension, and boxing, 27; peck, 9; ties, posts, and miscellaneous, 14 per cent.

STOCK AND SEASONING.

The great bulk of cypress is air-dried for periods of from 9 to 12 months. A representative mill in Louisiana, carrying about 45,000,000 feet of cypress in its yards, kiln-dried only 2 per cent of its lumber, but 60 per cent of its shingles and lath. Tank stock 3 inches thick should have about 18 months for air-seasoning. Except in an emergency, little of the high grades is run through the kiln, since checks and raised grain often appear, but some mills kiln-dry the commons, and so hasten their disposal. Because of the large water content, green cypress shingles are very heavy. Kiln drying effects a reduction in weight of about one-half. For doors and other high-grade products, manufacturers call for lumber dried for from 10 to 16 months, followed by kiln drying for from 3 to 20 days. Close mill utilization and the demand of the trade for air-seasoned cypress in a very large assortment of sizes and forms are the reasons why cypress mills carry a very much larger stock than mills of equal capacity operating in most other woods. Such large stocks are not turned over rapidly, and mills usually carry some lumber 2 or 3 years. The durability of cypress and its freedom from bluing and other injury affecting most woods account for the prevalence and entire success of open-air seasoning and slow handling of the stock.

MARKETS AND LUMBER PRICES.

Cypress was for a long time a little-known wood, used for the most part locally in the manufacture of shingles. It made but slow progress in the general market, and was subject to frequent fluctuations, which were annoying and costly to operators with capital tied up in standing timber and manufacturing plants. Now it has come into national prominence and there is a strong domestic demand for it. Although the larger part of the entire cypress cut is marketed in the region east of the Mississippi and north of the Ohio River, users and manufacturers in the Central and the Middle Western States are realizing more and more the value of cypress for certain purposes. The redwood of the Pacific coast has been to some extent a competitor of cypress, and cheap transportation through the Panama Canal may perhaps bring it into the eastern markets in larger quantities.

In 1914 the average mill-run price of cypress in Louisiana was about \$23.50 per thousand feet.¹ It is interesting to note that during the 12-year period following 1900 the price of northern white pine increased by \$6.44 and that of cypress by \$6.77. Cypress for many years has led all other conifers or "softwoods" in the average mill-run of its product. In 1899 cypress was 63 cents ahead of northern white pine, its nearest competitor; in 1907, \$2.61 ahead; and in 1914,¹ it led by about \$4.40.² Pecky cypress, for which there is a good market, usually brings the millmen \$8 to \$10 per thousand; commons, from \$10 to \$20; shop, \$20 to \$25; selects, \$28 to \$35; and clears, \$35 to \$45. These are round figures, but suffice to show the range of values. The cost of cypress to the wood-manufacturing industries throughout the United States, during the period of 1910 to 1912, averaged about \$26.95 per thousand board feet f. o. b. cars at the factory.

STUMPAGE.

In the early years of the cypress industry practical lumbermen with business foresight began to accumulate cypress holdings, which were then popularly considered of small value. The flat swamps in which cypress flourishes seemed to offer insurmountable obstacles to cutting and getting out the timber to a point where it could be manufactured into merchantable products. Along streams subject to high spring floods the situation was more favorable. Pine lands were still relatively cheap; and cypress swamps, on account of their accredited inaccessibility, were looked upon by the settlers as of little value. Large tracts of overflow lands in Louisiana and Florida acquired by speculators for 25 cents up to \$1 per acre, are now worth from \$70 to \$125 for the standing cypress alone, and are not really available at that price.

Stumpage values of cypress have become quite uniform, no doubt on account of the relatively few hands in which the remaining supplies are held. Along the Atlantic coast, where the bodies of cypress average smaller than in Louisiana and Florida, somewhat lower stumpage prevails. The cost of production, however, is relatively greater, but is offset a little by the shorter distance to the north-eastern markets and also influenced somewhat by the lower intrinsic land values in the region. A stumpage value averaging about \$8 per thousand feet is quoted for much of the best cypress throughout the Gulf region. This decreases in Florida and up the Atlantic coast to a more representative value of \$6 to \$7 per thousand for good

¹ Based upon 14 special reports to the Forest Service of average prices during 1914 from 5 of the larger mills in Louisiana. This is doubtless higher than for the whole cypress region. Figures for 1899 and 1907 are based upon Bureau of Census reports.

² The average price of northern white pine for 1914 was \$19.13, based on 27 reports during year from 8 large mills in Minnesota and Wisconsin; special reports to the Forest Service.

tracts of cypress timber. Seven sales in Louisiana in 1914, aggregating 45,000,000 feet were made at prices reported as ranging mostly from \$3.50 to \$8.25, but reaching nearly as low as \$2 per thousand feet, probably by reason of some condition such as scattering or inaccessible stands. Over 270,000,000 feet in Florida, comprised in four tracts, sold in 1913 at prices reported as ranging mostly around \$3 and \$3.50 per thousand feet. Assuming an average cost of manufacture of \$13 and a legitimate profit of \$2.90 per thousand feet, on the basis of the average mill-run price in Louisiana in 1914, the operator is realizing \$7.63 on his stumpage. A lower quality of standing timber, increased cost of manufacture, and lower average mill-run values will bring the returns from stumpage down to averages estimated mostly at \$3.50 to \$5.50 per thousand. It is apparent that at the present lumber prices, even with the upward tendency in cost of manufacture, prospective operators can afford to pay \$6 to \$8 for good cypress stumpage and make a reasonably good net profit.

LIFE HISTORY OF THE TREE.

Cypress is a tree of ancient lineage. Forest remains show that, prior to the glacial period, cypress, along with the redwood, incense cedar, the ginkgo (now of China), and several hardwoods, grew in abundance in the Arctic regions of both North America and Europe.¹ By subsequent climatic changes these species were driven southward along widely separated lines. The ginkgo descended the coast of China, the redwood the western coast of North America, and cypress the eastern coast to the warm south Atlantic and Gulf regions.

BOTANICAL FORMS.

Among botanists at least two forms of cypress are commonly recognized. These two forms overlap in geographical range and intergrade to such an extent that it is often difficult and sometimes impossible to distinguish between them. The differences, moreover, become less apparent as the tree increases in age.

When found distinct, the main form is characterized by flat leaves arranged in two ranks along the horizontal branchlets, wide-spreading limbs, and thin, comparatively smooth bark. The most common type of the other form (*Taxodium distichum* var. *imbricarium* Sarg.)² is distinguished by its small, asicular or appressed leaves, smaller and more ascending branches and branchlets, and thick, strongly furrowed bark (Pl. X). More recent investigation has added to the above some minor characteristics of the wood and differences in rate of growth, which are discussed elsewhere under appropriate

¹ Fisher, E. A., *Memoirs of the Museum of Comparative Zoology, Harvard University*, Vol. XVI, No. 1.

² Various held among botanists to be a variety or distinctive species.

headings. Each of the two forms, however, within itself presents real variations in leaf, branch, bark, and wood.

There are indications that the varietal form (var. *imbricarium*), which is more abundant over the Atlantic Coastal Plain than elsewhere, is undergoing a gradual botanical segregation during its assumed northward migration from Florida, and has been since the close of the glacial period. Progress in segregation is necessarily slow on account of the heaviness of the seed and its exacting moisture requirements for successful germination. Evidence points clearly to soil conditions, particularly acidity and drainage, as fundamental factors causing the botanical variation of cypress. The range of the imbricate form, so far as at present known, is generally coincident with the limits of the Atlantic Coastal Plain, but extends southward into northern Florida and westward to Alabama. The main species, on the other hand, finds its most congenial home along the Gulf Coast and up the Mississippi Valley in the deep alluvial soils.

OCCURRENCE.

The close restriction of cypress to very wet situations suggest two explanations: (1) That the species requires much water and is in reality a semiaquatic or mud-inhabiting species, or (2) that it has been forced to these unfavorable situations because of inability to compete with species better adapted to occupy the more favorable uplands.

Close observations on young cypress agree in furnishing evidence that, in its early stages, cypress is very exacting and successfully establishes itself only in situations of very abundant moisture. Subsequently, however, seedling growth is noticeably more rapid on better drained situations. These observations lead to the conclusion that in extremely wet situations cypress, in a greater or less degree, is tolerating conditions not generally favorable to the normal thrifty growth and development of the tree. In other words, the inherent soil and moisture requirements of cypress after its earliest stages are to be looked upon as very similar to those of many of the hardwood timber trees which thrive best in a deep, loose, well-drained, fresh, rich, sandy or clayey loam, containing humus and available mineral food, and well supplied with soil moisture.

Broadly speaking from a geological standpoint, cypress therefore belongs characteristically to young lands. Cypress is the dominating tree in the forests of the alluvial lands of the South. It advances slowly, but ahead of all other trees, as river and sea marshes gradually build up, flourishes in the deep alluvial soils submerged for a portion of the year, and later is driven out by the competition of hardwoods as the lands are further built up and become drained.

Within its natural geographic range, cypress occurs locally on quite widely different situations, all alike, however, in their swampy character. These may be grouped broadly under four classes, differing chiefly in the amount and acidity of the water, and, to some degree, in the composition and texture of the soil.

ALLUVIAL SWAMPS.

Swamps traversed by rivers or creeks which fluctuate in height and carry considerable solid matter in suspension are classed as alluvial river swamps. The overflow lands of the lower Mississippi River are among the richest and deepest alluvial soils in the world. Other alluvial streams are the Peedee, Santee, Savannah, Apalachicola, and Mobile Rivers. Broad river deltas or estuarine swamps, occurring at the mouths of some of these, take the form of an intricate net work of narrow channels. The water is always more or less muddy, but because of its breadth and its closeness to sea level is subject to only slight seasonal fluctuations. During the summer and fall the water in these swamps becomes stagnant and because of its acidity is rather unfavorable to tree growth. The continuous saturation of the soil and relatively slight fluctuation in depth of water are favorable to cypress seed germination.

Cypress reigns supreme over extensive areas of the flat delta region of the lower Mississippi. The bayou or river is bordered on both sides by a natural levee, back of which comes a succession of sloughs and low ridges leading into a deep swamp often miles in width. Over the ridges cypress gives way to oaks, red gum, ash, red maple, honey locust, hackberry, and a few less important hardwoods. The two forest types are represented graphically in figure 2, showing cypress confined mostly to permanently wet situations. Heavy cypress stands or "brakes" occupy the shallow lagoons and cut-offs of former river channels. Farther upstream the swamps of the large alluvial rivers are closely bordered by uplands which confine the water, causing deep inundation. Their surface is undulating and subject to complete overflow only during periods of high water. As a rule these swamps are better drained and, superficially at least, dry during most of the growing season. Growth is good and the quality of the timber produced is excellent.

NONALLUVIAL SWAMPS.

These swamps are located at or near the heads of watercourses and along clear-water streams, fed mostly by seepage and springs. They have dark or coffee-colored but clear water and muck or peat soils. The Dismal and Okefinokee Swamps (fig. 3) and many river swamps in Florida are typical of this class, and the water carries little sedi-

ment even during the flood season. Black gum and the bays in muck soils and southern white cedar in the peat soils are the main associates of cypress.

PINE BARREN "POND" SWAMPS.

The effect of variable moisture supply and highly acid soil is seen in the stunted and rather defective stands of cypress occurring in the ponds distributed thickly over the region from South Carolina to Florida. Here the starved cypress in its extreme form occurs and is commonly known as the "pond" cypress. In these situations cypress has practically no competitor, although there is some scattered water gum, and, near the margin, Cuban pine, pond pine, and spruce pine.

COASTAL SWAMPS.

While cypress is a tree tolerant chiefly of fresh water, it reaches the coast and advances a little into brackish tidal water. Growth here is distinctly inferior, and the salty overflow during driving storms undoubtedly accounts for the early death of many trees. The tree is an inhabitant of the fresh-water wooded swamps in distinction from the open grassy everglades and "prairies" of fresh water on the one hand and the coastal marshes and salt-water mangrove swamps

on the other. Many of the cypress "brakes" or cut-off sloughs represent the gradual filling of marshes and lagoons, which in a previous geo-

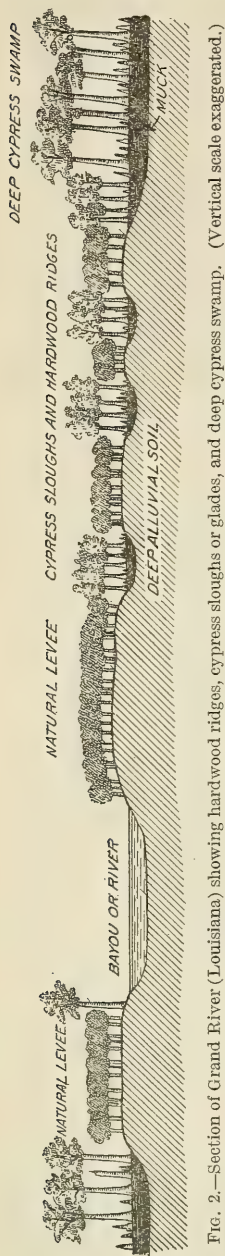


FIG. 2.—Section of Grand River (Louisiana) showing hardwood ridges, cypress sloughs or glades, and deep cypress swamp. (Vertical scale exaggerated.)

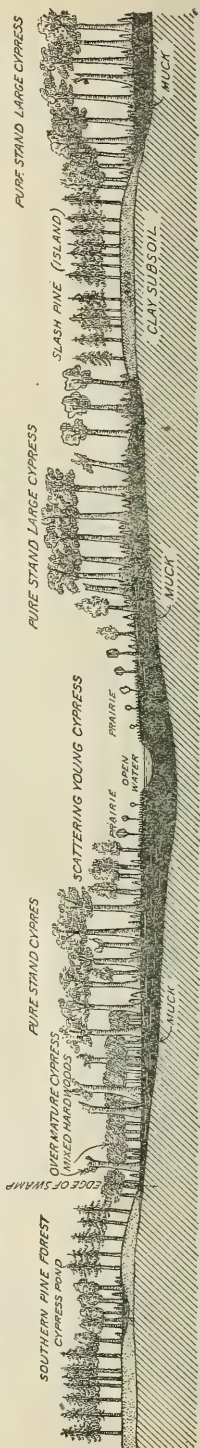


FIG. 3.—Section of Okefinokee Swamp (Georgia) showing open water, prairie, and various stages of young and old cypress stands. (Vertical scale exaggerated.)

logical period, as arms and bays of the ocean, extended far into what is now the Coastal Plain and great central valley.

LONGEVITY.

Cypress attains so great an age that the life periods of virgin stands are better spoken of in terms of centuries than of decades. Trees from 400 to 600 years old are very common, and those from 600 to 900 years are scattered through most virgin cypress stands. Individual trees 750, 820, and 845 years old were noted in the Okefinokee Swamp, 915 years in southern Louisiana, and about 1,200 years in the Flint River in southwestern Georgia.¹ Roth determined the age of a cypress near the Santee River in South Carolina² as over 1,200 years. There is considerable evidence that the greatest ages are reached in the region from South Carolina to northern Florida in the nonalluvial and slightly acid swamps subject to only slight differences in water level. The age attained seems to be limited chiefly by the ability of the tree to resist the attacks of fungi and force of the wind. Old trees die backward or downward during a period usually of one to three or four centuries. The last stage is usually a hollow cylinder consisting of sapwood from which the heart has been removed by decay (Pl. III). It is not improbable that the ages of these hollow veteran cypresses range from 1,000 to 2,000 years.

SIZE.

The prevailing size of mature trees in ordinary situations is somewhere about 3 to 5 feet in diameter at breastheight (4½ feet above the ground) by from 100 to 120 feet in height. In the highly acid soils of ponds and poorly drained, flat swamps the average maximum size is about 2 feet in diameter by from 50 to 70 feet in height. The largest trees scattered on ordinary sites are 7 to 8 feet in diameter.³ The maximum diameter for cypress is about 12 feet measured at breastheight. Maximum heights of from 140 to 150 feet are occasionally reached.⁴ In all cases, however, the culmination in height comes from one to four centuries earlier than the greatest diameter. The trunks of the trees of largest diameters are usually hollow at the base and more or less broken at the top.

FORM.

In form, cypress is a tall, straight-stemmed tree (Pl. I). In regions of prolonged inundations the tree usually develops a high,

¹ Ages very similar to the coast redwood of California, *Sequoia sempervirens* Endl.

² Forest Service Circular 19, p. 3.

³ See also discussion of volume on p. 41.

⁴ Sargent, C. S., "Manual of the Trees of North America," p. 72.

sometimes remarkably wide, buttressed or ridged base. Toward maturity this form at the base gradually disappears as a result of change in growth toward a cylindrical or columnar form. Another cause is geological in character. The remaining basal swell becomes buried during the course of several centuries by alluvial and peaty deposits, often to a depth of from 3 to 5 feet. In swamps not subject to high floods cypress usually has only slight basal swell (fig. 4). The narrowly pyramidal and symmetrical crown of smaller branches during earlier life gives way gradually during the second and third centuries to a broad, flat-topped crown consisting of a few wide-spreading, heavy limbs. This form persists during from two to four centuries; then decay, accompanied by winds, usually carries away considerable of the original top (Pl. III). In the open, cypress maintains a full crown of many small branches more cylindrical in form and very much less dense than the eastern red cedar.

BARK.

The bark shows extreme variation from a thick, deeply furrowed fibrous bark to a thin scaly one. The tree is very responsive to physical environment. In Florida, for example, near fresh, deep water, the bark at all ages is very thin, soft-fibered, and light brown in color, while in adjacent situations with sluggish or stagnant water the bark is thick and of a reddish color, the heartwood is darker and somewhat heavier, and the sapwood thinner and more uniform in width (Pl. X). In the great Wilmington Swamp of North Carolina the bark is prevailingly thick and firm. During logging it breaks apart into long, stringy fibers of a rich brownish-red color. The difference in bark thickness ranges mostly from $\frac{1}{4}$ to $1\frac{1}{2}$ inches. All intermediate gradations are present, and when the two extremes appear in the same region they are accompanied by different conditions of soil and moisture.

LEAVES.

The foliage consists of very small flat or needle-shaped leaves, arranged either in two ranks or closely appressed to fragile branchlets. Cypress is a conifer, but not an evergreen tree, and both leaves and branchlets are dropped in the fall. The wide variation in leaf form appears to be accompanied by corresponding differences in the amount and acidity of the water supply.

ROOT SYSTEM.

The conical base of cypress divides below the surface into about six to ten strong descending and spreading roots, which provide a deep anchorage for the tree. The form suggests that of a mushroom anchor. In addition to the descending roots, a number of large laterals extend outward near the surface like cables and form



FIG. 1.—CYPRESS MOSTLY SOUND AT 670 YEARS OLD, 60 INCHES IN DIAMETER. NOTE ROUGH BARK.



FIG. 2.—NUMEROUS SPROUTS ON HOLLOW STEM OF OVER-MATURE VETERAN CYPRESS; AGE ABOUT 900 YEARS.

MATURE AND OVERMATURE STAGES IN LIFE OF CYPRESS.



FIG. 1.—TYPICAL CYPRESS "POND" IN FLAT PINE WOODS, YIELDING POLES, TIES, AND SOME SAW TIMBER. IMPORTANT IN FUTURE MANAGEMENT OF SOUTHERN FORESTS. (GEORGIA.)



FIG. 2.—BASE OF 8-FOOT CYPRESS, ABOUT 1,200 YEARS OLD. (FLINT RIVER BASIN, GA.)

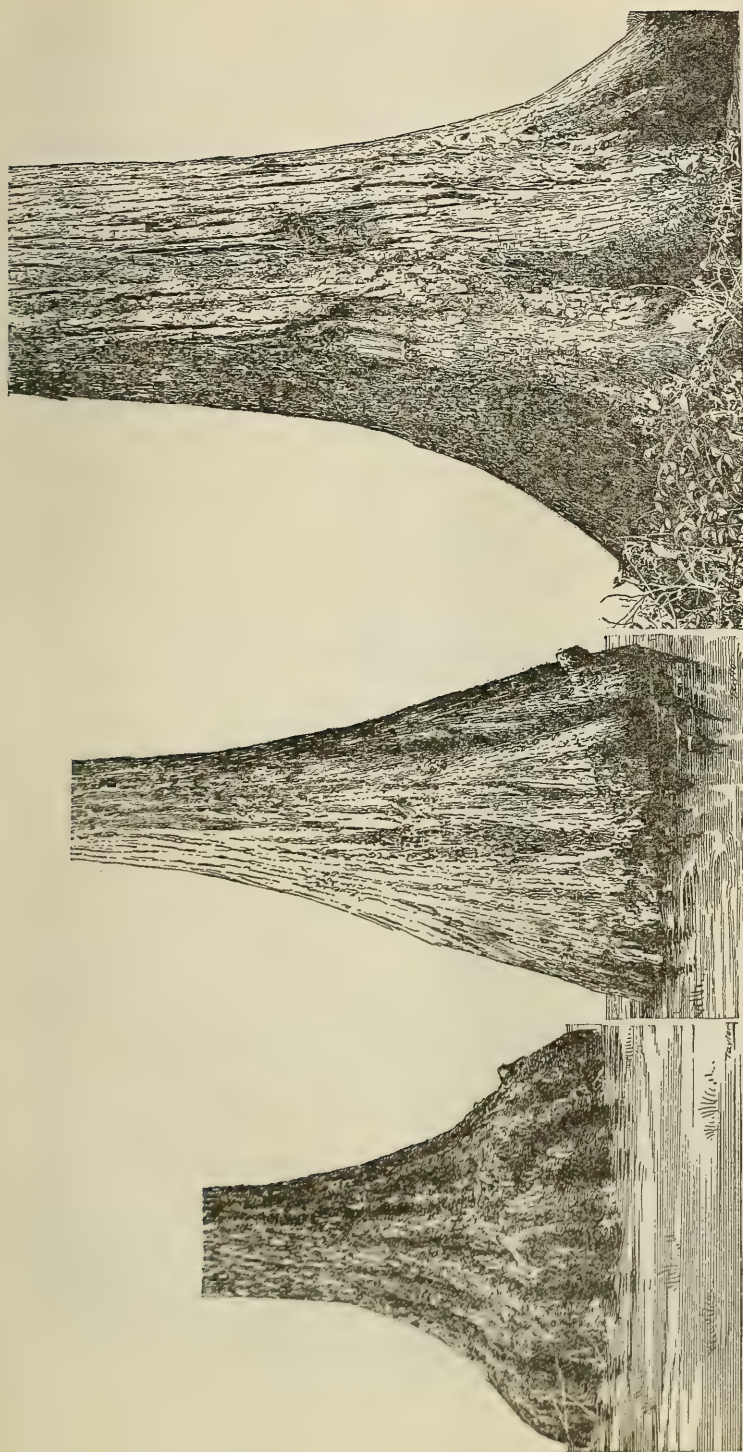


FIG. 4.—Variation in the basal form of cypress (from photographs). *a.* Low, very broad base in shallow, nonalluvial wet swamps (South Carolina); *b.* High, full basal swell in active or fresh water subject to deep inundations (Florida); *c.* Small basal swell typical of broad overflow region of the lower Mississippi River, and large inland swamps (Okefinokee Swamp, Georgia).

the widely spreading and branching superficial root system that has been more commonly recognized. The masses of roots at the base of cypresses have proved such an expensive obstacle to the digging of canals through swamps as to cause the financial failure of numerous timber operations dependent upon this form of logging.

CYPRESS KNEES.

The peculiar cypress "knees," or upright conic portions of the superficial root system, are of unusual interest. Knees occur mostly where water covers the surface for long periods, and their height corresponds rather closely to the average high-water level for the locality. Occasionally they reach heights of from 8 to 10 feet above low-water mark. Observations indicate further that in soft or yielding situations the root system is much more extensive and the knees correspondingly larger than in firmer soils. They appear in general to be as common in alluvial as in nonalluvial swamps, and in fresh as in stagnant or acid soils. The wood is light in weight, but peculiarly gnarled and twisted in structure, and therefore of extreme toughness. Except in their early stages, the knees are usually hollow, and they commonly die at once when the tree is cut.

In regard to the function performed by cypress knees very little is known by actual experiment. Wilson,¹ in a series of carefully conducted laboratory tests with cypress seedlings, found that when continuously submerged in water the superficial roots sent branches upward to the surface. This suggested the function of knees as breathing organs for the roots. In speaking of adaptations in marsh plants, Warming² states that in some trees and shrubs erect roots are developed which thrust their tips above water and convey air to the root system beneath in the mud and water, and on the authority of Kearney cites cypress as an example. At its lower end the knee has a downward-reaching, pronged root system, smaller but very similar in form and appearance to the main root system beneath the tree.³ The knee thus might be termed a sort of secondary tree, with the difference that it is composed of root wood. So far as is known there is no record of a knee budding or sprouting.⁴ It clearly is not developed for the purpose of reproduction.⁵

Although commonly credited in literature with serving the function of aerating organs, there is no definite proof from mature trees of the part played by knees in the economy of the tree. An experiment

¹ Wilson, W. P., formerly of University of Pennsylvania. *Proceedings Academy of Natural Science*, Philadelphia, April, 1889; see also *Forest Leaves*, Vol. II, p. 100-111.

² Warming, *Oecology of Plants*, p. 186.

³ Fig. 5 shows clearly this structure in trees photographed by Robert H. Lamborn. See *Garden and Forest*, Vol. III, p. 20.

⁴ Seedlings are occasionally found growing from seed which lodged and germinated in the hollows of decaying knees.

⁵ See "Effect of submergence," p. 38.



FIG. 5.—Cypress root system exposed 4 feet deep by wave action upon loose sandy soil following partial drainage of Lake Monroe, Fla.

has been started by the Forest Service in Louisiana to determine what effect the removal of the knees has upon the subsequent growth of the tree. The knees were removed from 15 trees and left on 5 near-by trees to serve as a check for later comparison. It should be noted that other swamp species, including tupelo gum, water ash, white bay, and others, do not produce knees, although they frequently occur in apparently the same situation where cypress has developed knees at least 2 to 5 feet in height. Some of the species do, however, develop slight humps or kinks in the surface roots.

Although cypress occurs chiefly on the most unstable and treacherous soils, it is one of the most windfirm of all southern commercial trees.¹ On what engineers would pronounce the most dangerous foundation it rears a shaft, often of massive proportions, for 60 to 90 feet in height, topped by a wide-spreading head of giant limbs with very numerous branchlets. It is obvious that the wind pressure at times upon a mature cypress is very great. However, Lamborn and Newberry,² both of whom traveled extensively in the southern regions, state that they do not recall having seen a living cypress overthrown by the wind. The great resistance offered by cypress to the force of wind is pointed out by Mohr,³ who visited the path of the severe tropical hurricane of September, 1892, along the Savannah River in Hampton County, South Carolina. He states that "not a single cypress was seen to have yielded to the fury of the storm, although the pines in its track were mowed down like grain before the reaper, and the sturdy live oaks and laurel oaks were uprooted."

The mass of interwoven horizontal roots, with the aid of hundreds of vertical roots beneath the knees, binds the associated soil materials and furnishes a stable support for the weight of the tree. The large sustaining force of cypress roots is thoroughly recognized by lumbermen and is utilized in the construction of logging railroads over swamps.

The mechanical function of the knees was pointed out by Lamborn,⁴ who investigated the subject from the standpoint of a mechanical engineer. In his conclusion he stated "that the most important function of the knees is to stiffen and strengthen the roots, in order that the great tree may anchor itself safely in a yielding material." Mohr in his thorough study of cypress reached the same conclusion.

In view of the requirements of cypress for an extraordinary root system for support in soft, yielding soils and the binding effect of the

¹ Elliot says: "The cypress resists the violence of our autumnal gales better than any other of our forest trees." *Botany of South Carolina and Georgia*, p. 643, 1824.

² *Garden and Forest*, Vol. III, p. 21.

³ Mohr, Dr. Charles, Manuscript report on cypress, based upon an extensive field study. Forest Service, Department of Agriculture.

⁴ Lamborn, Robert H. "The knees of bald cypress: A new explanation of their function." *Garden and Forest*, Vol. III, p. 21.

pronged and multiple roots below the knee, it appears very probable that the knees are developed not only for the purpose of increasing the supply of oxygen which the roots are able to obtain directly from the water, but of enlarging and strengthening the basal support. The evidence of this belief is (1) the general absence of knees in swamp soils superficially dry during most of the year, (2) the presence of knees where there is an excess of surface water for long periods, (3) the rise of the knees approximately to the height of the average flood level, and (4) the interwoven network of roots in the superficial root system, and the anchorage afforded by the mass of deep roots beneath the knees.

REPRODUCTION.

SEED AND GERMINATION.

Cypress has the power of reproducing itself both by seed and by sprouts from the stump.

Cypress cones ("balls") contain from 18 to 30 twisted, sharply keeled, or winged seeds¹ (Pl. XI). Large pockets or sacs in the cone are filled with an exceedingly sticky, red, liquid resin, unpleasant to the taste. This probably explains why the seeds are only in slight degree taken as food by either birds or rodents. The outer coating is thick and hard. When free from cone scales or other materials there are about 5,000 seeds per pound. Upon ripening in October and November, the seeds fall to the ground near the tree. Unlike the seeds of most conifers, cypress seeds are not scattered to any extent by wind and animals. Seed is borne in abundance. Some is produced almost every year, and full seed crops, so far as is known, occur at intervals of about every three years. Some of the seed is aborted or infertile, so that germination averages usually from 40 to 60 per cent.

Tests² of seed collected in the two Carolinas in the fall of 1913 gave from 55 to 65 per cent of germination (Table 5 and Pl. XI). The general average for seed from all sources is perhaps 40 to 50 per cent. Seeds stored indoors in a warm, dry room from November until the following April, 1913, gave 55 per cent germination, occurring mostly in five weeks and reaching completion in seven weeks. Some of the same lot after soaking in stagnant water in a warm room for six weeks gave 65 per cent germination, complete in two weeks from date of sowing. In another test seed which was kept continuously moist and aerated under a glass jar for a period of four months completed germination in seven days,³ with a total of 87 per cent germination.

¹ Size of seed averages from $\frac{1}{4}$ to $\frac{3}{4}$ inch long by $\frac{1}{4}$ to $\frac{1}{2}$ inch wide.

² Conducted by the writer in greenhouse flat at the Arlington Experiment Station, U. S. Department of Agriculture. The seed was collected at random from trees in North Carolina and South Carolina 50 to 100 years old, and conditions for the tests were practically ideal.

³ In June, 1913.

TABLE 5.—*Germination of cypress seed*¹ *in greenhouse test, Arlington Experiment Station, U. S. Department of Agriculture.*

Date of examination (1914).	200 dry seeds sown on Apr. 3, 1914.		20 soaked seeds sown on May 9. ²		50 moist seeds sown on May 16. ³	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Apr. 25.	13	6.5	-----	-----	-----	-----
Apr. 30.	46	23	-----	-----	-----	-----
May 6.	90	45	-----	-----	-----	-----
May 11.	100	50	-----	-----	-----	-----
May 16.	104	52	-----	-----	-----	-----
May 21.	107	53.5	8	40	-----	-----
May 23.	109	54.5	13	65	43	87.5
May 25.	111	55.5	13	65	43	87.5
May 30.	111	55.5	13	65	43	87.5

¹Seeds collected in October and November, 1913, in North and South Carolina, and stored in warm, dry room.

²Seeds from lot as above, soaked in stagnant water 6 weeks prior to sowing.

³Seeds from same lot as above, kept in moisture-saturated air for 7 weeks prior to sowing.

Over the extreme northern part of the tree's range very little of the seed matures.¹ Germination takes place at various times during the following spring. If it is early the seedling is exposed in the swamp to the extreme vicissitudes of periods of high water. If the seed is kept continuously submerged, it will not germinate.

The seed-bed requirements are a very abundant supply of moisture maintained for a period of from one to three months. Under these conditions the hard seed coats swell and soften, allowing the tender seedling to emerge. The young seedling is thus almost semi-hydrophitic in its early stages and develops well in completely saturated soil, though it does even better where there is some drainage. A bed of sphagnum moss seems to afford the best kind of seed bed, doubtless because of its capacity for retaining moisture in large quantities. Soft, wet muck is also favorable to successful germination.

SPROUT REPRODUCTION.

Cypress sprouts freely from the stump under ordinary conditions during the first 50 to 100 years. Sprouting from stumps 100 to 200 years old is not unusual. A coppice sprout 6 feet high was seen in Louisiana growing from the top of a stump over 300 years old cut about 14 years ago at the height of 8 feet. All of the sapwood had decayed except beneath the sprout, where living connection with the root had been maintained. Large, thrifty coppice occasionally sprouts from stumps up to 180 years old. In every such case observed the parent tree was of slow growth and therefore relatively small (Pl. VI). Economic reproduction by sprouts is rather closely restricted by the age and size of the parent stump. Stumps of vigorous stock up to the ages of 40 to 60 years, when cut in the fall or winter, may generally be counted on to send up healthy sprouts.

Slow-growing trees beyond the ages of from 60 to 90 years will not ordinarily reproduce themselves successfully by sprouting. The corresponding diameter limitation is seemingly about from 10 to 14 inches at 2 feet above the ground. Girdled trees die and will not sprout when cut in logging. Along the Atlantic coast, on relatively dry sites, cypress sprouts successfully from both the top and the base of the stump (Pl. VI). Along the Gulf and Mississippi Valley only sprouts from the top of the stump, or wounded cambium, have been observed (Pl. V), although root collar sprouts may also occur.

YOUNG GROWTH.

Young cypress, although quite unevenly distributed, is present in larger amount than is popularly believed. Stands of young growth occur abundantly in openings in deep swamps generally throughout its range, but are notably absent from the better drained areas or ridges and all older upbuilding portions of swamps.

Along the Atlantic coast cypress appears to be more aggressive both in sprout and seed reproduction than over the Gulf States and Mississippi Valley. In the more northern portion of its range the germination per cent of the seed is lower and young growth is much less abundant than farther south.¹ In the Mississippi Basin where the soil is rich, strong competition by numerous hardwoods and other plants appears to reduce the amount of young cypress. It is worth special note that cypress reproduction is extremely prolific in the countless shallow ponds and bay heads over the Atlantic coastal plain from North Carolina to Florida. In the extensive occupation of former rice fields in South Carolina, surface water instead of wind has been the chief means of distributing the cypress seed. Because of the light, delicate foliage and deciduous leaf habit, cypress seedlings and saplings when present are apt to escape casual observation. Young cypress is characterized by its coming in gradually but growing persistently, often beneath the partial overhead shade of other species, until it reaches its normal position of dominance over all others in the forest stand.

A very wet swamp along the Santee River near Ferguson, S. C., contained a heavy stand of 2-year-old cypress seedlings from 14 to 20 inches² in height (shown in Pl. VIII). The maximum stand counted in this locality contained 219 seedlings in a square rod. This density, 35,000 per acre, was greater than that of any other species locally except overcup oak. The average stand on 500 to

¹ Kearney reported cypress in the Dismal Swamp as reproducing itself very slowly, so that an area once cut over for merchantable cypress was regarded by the lumberman as permanently exhausted. Seedlings were reported, however, as being plentiful upon narrow tracts of marshy land around the edge of Lake Drummond. (Report of a Botanical Survey of the Dismal Swamp Region, U. S. National Museum, Vol. V, No. 6, Division of Botany, U. S. Department of Agriculture, by T. H. Kearney.)

² Age confirmed by section examined under the microscope, Forest Service, November, 1913.

1,000 acres was estimated at between 4,000 and 6,000 per acre, although irregular in distribution and absent from many small areas. In general, it is more scattered and is confined to the wetter situations. In the green swamp of North Carolina young cypress was seen competing well with red maple, water oak, ash, and tupelo gum in tracts logged from 3 to 6 years ago. In four years cypress here grows to be from 4 to 6 feet high (Pl. VI). In the great delta region of southern Louisiana former cuttings were seen in which cypress reproduction was just as successful as willow and tupelo gum in taking the ground where seed trees had been left (Pl. V). Mohr,¹ who made extensive examinations of the region, says:

In the dense forests which, for example, cover the shallow lakelike expansion of the lower Atchafalaya River and the flooded banks of the numerous channels of the mouth of the Red River, where the cypress occurs almost pure, reproduction takes place after the larger trees are removed.

In swamps a very decided change in the vegetation usually follows lumbering. This is due to the free exposure to light of surfaces previously under the dense shade of a high cypress forest, and the presence of many of the herbaceous plants and trees at the time of logging. Thus, cypress appears similar to white pine, northern spruce, and other species in returning slowly and fighting its way back, following heavy cutting in former virgin stands. Furthermore, in the case of cypress, if its former home has been upbuilding and becoming drier, the chances are against successful reproduction and the return of the species even in reduced numbers.

The cause for incomplete and unsatisfactory stands of young cypress are mainly:

- (1) Inadequate supply of seed trees, due to close lumbering and the smashing of practically every remaining cypress of seed-bearing age by modern methods of steam logging.

- (2) Inherent requirements of the seed and young seedling for moisture in great abundance for germination and early seedling development, which place the species at a disadvantage when in competition with others on upbuilding swamp areas.

- (3) Heavy seed, which, unlike the seed of most conifers, is not freely scattered by wind.

- (4) Death and injury of young seedlings, due to submergence and sometimes to stream deposition during periods of flood waters.

There is no record of close observations on the endurance of cypress seedlings under partial or complete submergence. The infrequent coincidence of heavy seed crops and favorable water levels during at least the first season following germination undoubtedly is an important factor in the amount of cypress reproduction. Delayed or long continued flood periods may result in very late germination of the

¹ Mohr, Charles, Forest Service manuscript, 1898.



FIG. 1.—ELEVEN-YEAR-OLD SEEDLING CYPRESS (X) AND STUMP SPROUT (XX) OF SAME AGE IN CUT-OVER AREA. WILLOW AND TUPELO GUM IN MIXTURE. (GRAND RIVER.)



FIG. 2.—VIGOROUS CYPRESS COPPICE, 12 YEARS OLD, 6 TO 10 INCHES IN DIAMETER. NATURAL REFORESTATION FOLLOWING LOGGING IN LOUISIANA.

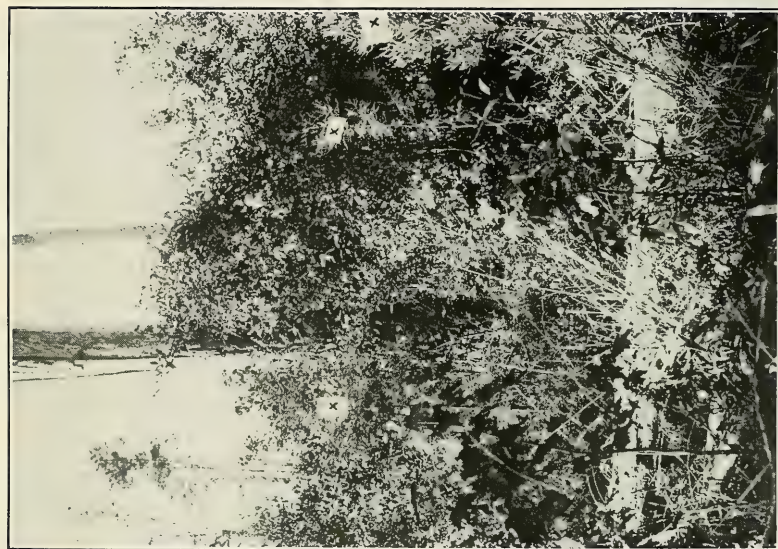


FIG. 1.—CYPRESS SEEDLINGS (X) SUCCESSFULLY COMPETING WITH HARDWOODS IN REFORESTING AN OPENING LOGGED 5 YEARS AGO.



FIG. 2.—SPROUT REPRODUCTION FROM TREE 170 YEARS OLD. NOTE VIGOR OF SPROUTS FROM BASE OF STUMP.

NATURAL REPRODUCTION IN THE GREEN SWAMP, NORTH CAROLINA.



FIG. 1.—CYPRESS ADVANCING INTO FORMER MARSH OR "PRAIRIE" AS THE PROCESS OF UPBUILDING PROGRESSES.



FIG. 2.—POLE CYPRESS, 140 YEARS OLD, NEARLY FILLING A SMALL "PRAIRIE" AND SURROUNDED BY CYPRESS 265 YEARS OLD IN FOREGROUND.

RELATION OF CYPRESS TO LIFE OF SWAMPS—OKEFINOKEE SWAMP.



FIG. 1.—DENSE STAND OF 2-YEAR-OLD CYPRESS REPRODUCTION IN OPENING.

Maximum stand of 219 seedlings per square rod, 15 to 20 inches in height. Water ash and tupelo gum associates in flat wet swamp. (Santee River, S. C.)



FIG. 2.—CYPRESS SAPLING AND POLE REPRODUCTION FOLLOWING LOGGING.

Logging 18 years ago made opening, now filled with young cypress from 7 to 16 years old. (Southern Louisiana.)

seed, which increases the susceptibility of the immature seedling to winter freezing.

Stands of mature cypress, but rarely any of young growth, occur on the ridges in the undulating swamp bordering such alluvial rivers as the Santee, Apalachicola, and Mississippi (fig. 2). The recent up-building of many of these ridges by the deposition of silt and other material during floods is clearly apparent; likewise the later excavations of some of them by swift flood currents, exposing the embedded bases of mature standing cypress trees. With the natural limitation of reproduction to the very wet sites, second-growth cypress is irregularly distributed in swamps, being found mostly in openings and especially on newly formed low, wet mud bars and banks (Pl. VIII).

Reproduction is notably more abundant in localities where cutting has been conservative than where logging has made a clean sweep.

The early float method of logging destroyed very little growing stock, the pull-boat method considerable, and under present methods of clean cutting the overhead-cableway skidder effects almost complete destruction of any part of the forest which happens not to be taken.

Evolution of the Okefinokee Swamp.—The relation of cypress reproduction to the progressive changes in the history of large inland swamps is interesting. This relation is intimate, and the comparative ages of various portions of the swamp—for example, the Okefinokee Swamp in Georgia—can be told approximately by the age and distribution of cypress in the forest stand.

Remnants of the original lake may be seen in the Okefinokee Swamp in the scattered bodies of open water. These are bordered by "prairies," or treeless marshes of considerable width (Pl. VII). In passing outward from the central open water toward the higher or older portions, one successively finds (a) widely scattered clumps of young, slow-growing cypress which obtained a foothold on the vegetable mounds or tufts, (b) dense stands of slender pole cypress, (c) mature stands of large-size trees where the swamp floor of humus and mulch has become quite stable, (d) overmature cypress trees scattered in a stand of black gum and white and red bays, and (e) on the outer and oldest portion, a high forest of pure hardwood with hardly a remnant of the former cypress stand. These successive stages are well shown in figure 3 on page 22. At the extreme edge of the swamp this type changes abruptly to a pure forest of either longleaf or slash pine over the broad, sandy pine flatwoods. The marshes range in size from a few rods in diameter ("alligator holes") to several hundred acres. One small "prairie" contained a few 10-year-old saplings surrounded by a large pole stand 140 years old, which in turn was inclosed by a marginal, even-aged stand of thrifty

cypress about 265 years old (Pl. VII). Outside of these successive age classes in the form of concentric rings, the main stand was mostly 300 to 400 years with a considerable mixture of bays and gum. In logging, only a few of the larger trees in the 140-year-old class and practically all of the surrounding older stand were taken.

The subsidence theory.—The theory that the Atlantic and Gulf coasts are gradually sinking is held by some to account for the irregular and unsatisfactory reproduction of cypress. This theory of a general subsidence is one upon which authorities hold quite opposite views. Those who believe in subsidence indicate a rate of about one-tenth of a foot in a decade. Cypress seed, however, usually germinates the first year, and the seedling makes an average growth of from 10 to 18 feet in height during the first decade. The prevailingly better reproduction of cypress on low wet situations than on better drained or upbuilding soils, except near salt water, is an evidence against the adverse effect of any subsidence that may be in progress by either checking the incoming of reproduction or subsequently retarding its growth. The effects, if any, from subsidence at so slow a rate would be more apt to appear in the tree during periods measured in centuries than during the few years of the reproduction stage. On upbuilding lands cypress is clearly receding before the hardwoods, and similarly, the best reproduction of cypress is found in very wet situations, where it is equally the dominating and the advancing species over all associated swamp hardwoods.

DEMANDS UPON CLIMATE AND SOIL.

CLIMATE.

Cypress grows in a wide range of temperature. Its natural range extends from below the frost line in southern Florida northward to New Jersey. Its extended potential range takes it northward to a line connecting Massachusetts and Michigan, where it experiences minimum temperatures of about -20° F. More than 90 per cent of the total cypress stand is found at an elevation of less than 100 feet above sea level. In the Middle Atlantic coastal States the 100-foot contour marks the upper line of elevation, while over the central Mississippi Basin the species prevailingly stops at an elevation of about 500 feet. Hundreds of miles west of the great coastal swamps cypress reaches large size around the edges of deep hollows on the Edwards Plateau of Texas at elevations ranging from 1,000 to 1,750 feet. It appears that atmospheric moisture and rainfall both play an unimportant part in the distribution of cypress, as compared with soil moisture.

SOIL.

Cypress thrives in a wide variety of soils, including muck, clays, and the finer sands. It has been commonly reported that sandy

soils are very unfavorable, but this is only in part true. Unable to thrive in impoverished or sterile sandy soils, cypress stands in a class with the ordinary hardwoods as distinguished from most of the other conifers, notably the pines. Of these, longleaf pine endures the deepest, driest soils of the South and thus presents the most striking contrast to cypress, since the two occur extensively on adjacent but extremely different sites. Sandy soils dry out quickly near the surface, thus preventing cypress from getting a foothold in the seedling stages. The beds of the larger Atlantic and Gulf coastal rivers are composed of varying soils of sandy and silty character. It is here that cypress finds the optimum conditions for its development. Except in the extreme northern portions of the State where the Lafayette clays are present, cypress in Florida occurs largely in sandy soils, but only where soil moisture is abundant and relatively permanent. Similarly, in the typical humus soils, such as occur in the Everglades, the presence or absence of cypress seems to depend upon the depth of surface drying during periods of drought and the presence at least of a minimum mineral component in the soil. In the shallow ponds scattered over the lower Atlantic and Gulf Coastal Plains, where natural conditions for advanced tree growth are decidedly unfavorable, both soil and moisture conditions appear singularly favorable for cypress-seed germination, and natural reproduction here is uniformly the most abundant in the whole geographical range. The poorly nourished, inferior form of "pond" cypress is found on this class of shallow, poorly drained soils.

On the whole, it may be stated that cypress finds its most congenial situation for adult growth in a deep, fine, sandy loam supplied with an abundance of soil moisture and well drained—the requirements for practically all trees. Cypress is usually found, however, in poorly-drained localities. Where cypress does occur on ridges or bars it is practically certain that the latter have been built up by natural changes and stream deposition since the incoming and early stages of the stand. The character of the growth of cypress planted on upland soil in the Ohio Valley and the North Atlantic States (see p. 64) furnishes corroborative evidence of the general correctness of the above conclusions, which were reached through a careful comparative study of the various qualities of situations where cypress occurs, and of the respective ages and rates of growth of the stands.

LIGHT REQUIREMENTS.

The quantity of light required by a tree for active growth is indicated by its tolerance. Since the various tree species vary widely in their respective demands for light, the tolerance of a species has much to do with its manner of occurrence in the forest stand. Cypress is able to endure partial shading for periods of considerable length,

but requires a good degree of overhead light for normal growth. Under moderate shading it makes a persistent but less rapid growth than in the open. Since there is no fixed scale for grading trees in respect to their tolerance, general classes only are used. Cypress is undoubtedly to be classed as moderate, or about midway, in the scale of tolerance. It appears to thrive with less light than tupelo gum, cottonwood, honey locust, red gum, ash, and willow, but requires more light than red maple, oaks, elm, hackberry, black gum, slash pine, and white cedar. Overhead light is required, but side shading accelerates height growth and natural pruning of limbs. In full stands cypress characteristically has a clean, smooth stem and small crown. In other words, it cleans itself readily of branches. The narrow-leaf form, or "pond" cypress, is less tolerant of shade than the broader, two-ranked or regular form of cypress.

SUSCEPTIBILITY TO INJURY.

In comparison with the important southern pines and hardwoods cypress ranks high in resistance to injury. The thin bark offers slight protection against fires, but these rarely occur in cypress stands except along the narrow margins of the deep swamps and over the shallow ponds. At intervals of many years dry periods occur, during which fire does considerable injury in the larger swamps. The general fire risk, however, in timber and logging is practically negligible. Insect attack on living trees may likewise be counted as of little consequence, and up to the age of 200 years, or about the average life of its common associates, cypress suffers only small injury from fungous disease.

CAUSE OF PECKY CYPRESS.

The fungus causing the well-known "pecky," "peggy," or "botty" cypress is present everywhere and in varying degree, but more particularly in virgin cypress stands during the overmature stage. It is found in all ages down to saplings, and occasionally infests stands from 75 to 150 years old. This fungus attacks only the heartwood of living trees, and destroys the wood in spots. The rate of growth and progress of infestation is very slow. The isolated disease centers gradually increase in size and force, resulting eventually in the destruction of all intervening wood and the formation of hollow limbs and trunk.

The life history of this fungus eluded careful investigation and was for many years only partially known. Von Schrenk made detailed investigations of the nature of pecky cypress,¹ and pointed out the striking similarity of the disease to the peculiar honeycomb rot in incense cedar (*Libocedrus decurrens* Torr.), a species of the Pacific

¹ Von Schrenk, Hermann, Missouri Botanical Gardens, 11th Annual Report, 1900, pp. 23-77.

coast which, like cypress, represents the flora of a previous geologic epoch. He did not, however, determine the cause of the disease. The junipers also are affected in a somewhat similar manner. Among other things, Von Schrenk pointed out that pecky cypress is most prevalent in the southern range, and decreases in amount toward the north in the colder climate. Investigations by the Bureau of Plant Industry, United States Department of Agriculture, in 1913, led to the discovery by Long¹ of the "punks" or fruiting bodies of this fungus on cypress and its identification as *Fomes geotropus* Cooke, a tropical and subtropical species infesting many of our southern hardwoods, and closely related to *Fomes ulmarius* Fries. of Europe. In the base, the presence of water in abundance causes vigorous activity, and the entire heartwood is frequently destroyed, leaving hollow butts. The fungus is most prevalent, however, in the upper portions of trees, where it gains entrance, presumably, through wounds in the bark. On account of lack of sufficient moisture, its growth here is very slow. In the case of broken-off tops, cavities are formed in which rain water collects, thus affording conditions of moisture and free air circulation favorable to the leaching and disintegration of the resin in the wood and the resultant advance of the fungus. Loggers sometimes discover large, apparently sound cypress trunks consisting of only a shell of sapwood above the base. The pecky fungus is perhaps indirectly the most active cause of the death of cypress, since it eats out the supporting heartwood, allowing the wind to tear down piece by piece the remaining portions of the tree. As indicated on page 16, pecky cypress is one of the standard grades of lumber. Because it is strong in proportion to its weight and because, so far as is known, its lasting qualities are not affected, it is valuable, and is used extensively for many purposes.

The immunity of cypress wood to bluing gives it a marked economic advantage both in logging and milling. At present great numbers of logs that have lain for 15 to 25 years in the swamp are being utilized. The lumber from such logs averages somewhat darker in color, but in general can not be distinguished from stock freshly felled.

INSECT DAMAGE.

Extensive investigations conducted by the Bureau of Entomology, United States Department of Agriculture, show that the principal insect damage to bald cypress is that caused by several species of pinhole borers or ambrosia beetles in the wood of girdled trees, logs cut from living trees, and freshly sawed lumber.

For full information regarding this kind of injury and the methods recommended for preventing losses, the reader is referred to Circular

¹ Long, W. H. A preliminary note on the cause of "pecky" cypress. *Phytopathology* 4, No. 1: 39, F., 1914.

82 of the Bureau of Entomology, United States Department of Agriculture, entitled "Pinhole Injury to Girdled Cypress in the South Atlantic and Gulf States;" also Circular 128 of the same bureau,¹ entitled, "Insect Injuries to Forest Products."

WIND.

Wind causes shake in the wood, and breaks down living trees when badly weakened by decay. The majority of trees, especially the veterans, reach their death through the combined agencies of the pecky fungus, causing hollow hearts, and wind pressure. Strong inshore gales combined with periodic high seas produce storm tides which invade and submerge large areas not usually reached by salt water. Unable to withstand exposure of this sort, the cypress in low seacoast swamps is sometimes badly injured both by the saline matter in solution and the mechanical force of high waves. Probably this in great measure accounts for the large amount of defective cypress sometimes seen along the coast, particularly on low advancing river estuaries and deltas. The breaking of protecting barrier sand reefs, the opening of tidal inlets, and other local changes in shore lines sometimes cause a permanent invasion by the sea which injures or kills the standing forest.

EFFECT OF SUBMERGENCE.

The effect of permanent submergence upon the subsequent growth of cypress depends chiefly upon the rate at which it takes place and the amount of deposition which results. The tree is apparently not injured by deep submergence for periods of a few weeks only. Instances of rapid inundation by the sudden subsidence of land areas are rather frequent over the comparatively recent land formations where cypress finds its home. Shaler² cites a conspicuous instance in the Mississippi basin of western Tennessee in which extensive tracts of cypress land were flooded by subsidence accompanying the earthquake of 1811. Wherever the sinking brought the water permanently to a considerable depth above the former level the trees died. About 1870 he observed that Reelfoot and other lakes were covered by the stately columns of the trees thus killed during the lapse of over two-thirds of a century. Near the outer margins the trees survived. In artificial flooding, where the permanent water level is brought above the knees, the trees have been reported by some observers to be injured or killed.

¹ The supply of Circular 82 is exhausted; Circular 128 is listed as available from the Superintendent of Documents, Washington, D. C., price, 5 cents. Both are on file in all larger public libraries.

² *Memoirs of Museum of Comparative Zoology*, Harvard College, Vol. XVI, pp. 1-11.

In Chipola Lakes (locally known as "Dead Lakes"), tributary to the Apalachicola River in Florida, a subsidence of from 3 to 6 feet has been followed by the gradual dying of a heavy, pure cypress stand over a nonalluvial area about 10 miles long by about half a mile in width. Many trees, however, still persist with a fragment of life after standing in clear water about 70 years. Repeated top fires, started by fishermen and others, during dry seasons, in the dense festoons of Spanish moss have left clear evidence of their part in the killing of the stand. On adjacent lands along the Apalachicola River, where alluvial deposits kept pace with the subsidence, the bases of mature cypress trees lie deeply buried, yet very old trees are still living. A splendid young stand of cypress and ash about 48 years old covers the deep, rich alluvial soil, indicating the close of the period of rapid subsidence. The effect of draining swamp lands is discussed on page 53, where it is shown that the effect of ordinary draining is slight.

GROWTH.

In considering the growth in diameter, height, and volume, it is essential to distinguish clearly between trees grown in the virgin forest and those grown in the open, or second growth. Because the rate of development is so widely different in the two cases, it is essential to have two sets of tables for comparison. Measurements indicate little difference in the rate of growth of cypress between the warmer and the cooler regions of its natural distribution. Trees planted in Pennsylvania and Ohio, north of its natural range, are growing about as rapidly as the natural growth in various parts of the South.¹

Wounds in the bark are healed at the rapid rate of three-fourths to 1 inch per year on each side of the wound. One tree 330 years old overgrew a fire scar 6.8 inches across in 4 years. Most remarkable is the continuance of life in the stump sometimes for several years without the formation of vegetative sprouts. In this manner the tops of stumps from 18 to 24 inches across occasionally are found fully calloused over and living several years after cutting.

GROWTH IN HEIGHT.

Cypress seedlings grow at a very rapid rate. This aids the young tree in reaching above the ordinary levels of surface water. Few if any conifers besides cypress commonly reach heights of from 8 to 14 inches the first season and from 16 to 24 inches the second season. (See Table 6.)

¹ See "Cypress under Cultivation," p. 64.

TABLE 6.—*Height growth of cypress saplings under full light in southern Louisiana.*¹

Age.	Height.	Age.	Height.	Age.	Height.
<i>Years.</i>	<i>Feet.</i>	<i>Years.</i>	<i>Feet.</i>	<i>Years.</i>	<i>Years.</i>
1.....	0.8	5.....	5.5	8.....	11.4
2.....	1.7	6.....	7.0	9.....	14.8
3.....	3.0	7.....	9.0	10.....	18.8
4.....	4.3				

¹ Based upon age counts of 110 trees from 3 to 32 years old. This and the following tables of growth and volume in Louisiana are based on measurements by F. T. McLean, Forest Examiner, Forest Service.

Second-growth or open-grown cypress in Louisiana averages 16 or 18 feet in height at 10 years, 31 feet at 20 years, and continues at a gradually diminishing rate until it reaches a full height of about 100 feet in the first 100 years. The height continues to increase during the next one to three centuries; then the fungus causing pecky cypress disintegrates the heartwood in the top and winds start the downward or backward stage in the height of the tree. The average heights of stands 350 to 500 years old are perhaps about the same as young virgin stands at 60 to 80 years; the prime stage in respect to height is approximately from 150 to 300 years. Individuals which live to be 600 years old probably spend about one-half of their time in the decadent stage.¹

Table 7 shows the height at various ages up to 100 years of second-growth cypress in Maryland and Louisiana supplied with abundant overhead light, as, for example, in logged areas. While the height growth of virgin stands may be interesting, knowledge of the rate of growth of younger stands is more valuable in figuring the profitability of managing young cypress forests. The three columns of growth in Table 7 represent three grades of favorableness of situation. In comparison, the slow height growth shown in Table 8 of trees grown under the heavy shade of virgin forests is very striking.

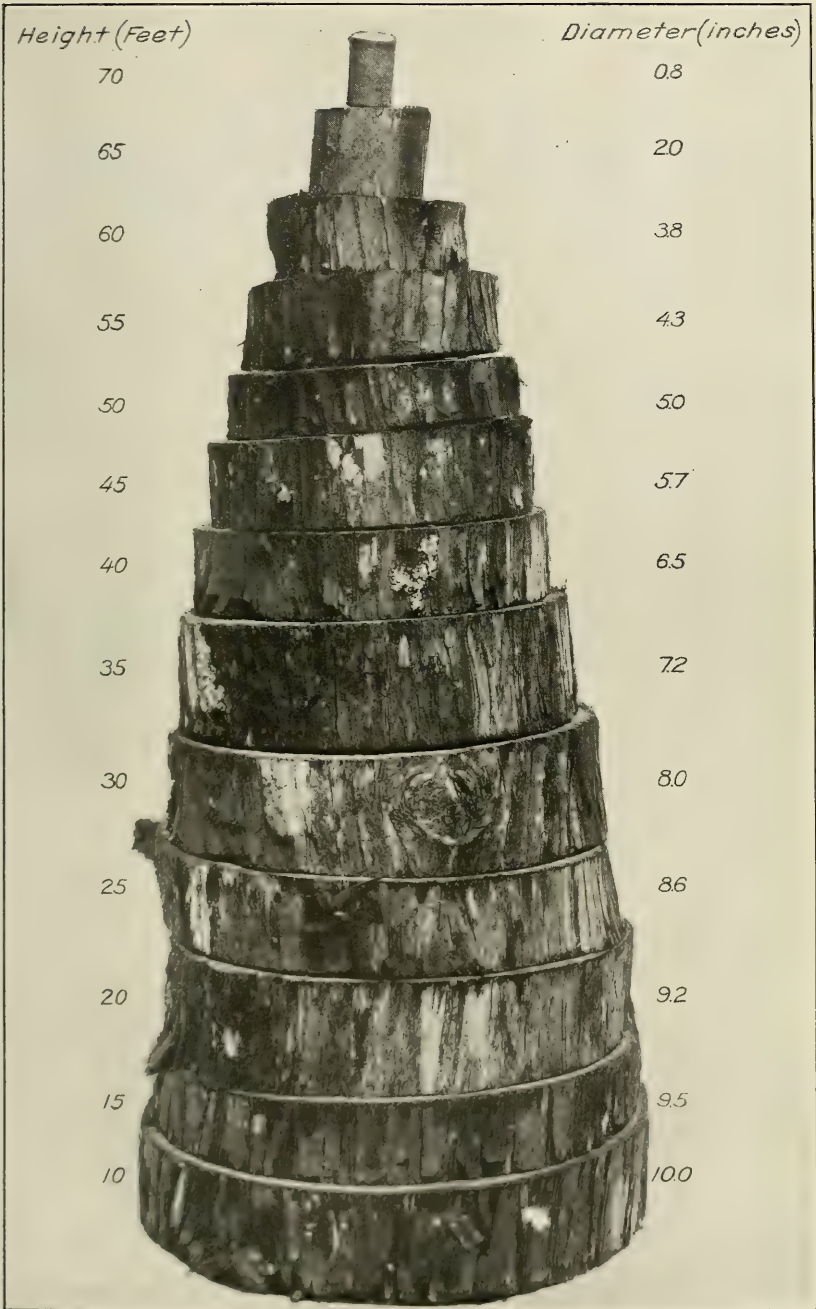
TABLE 7.—*Height of second-growth cypress on the basis of age.*

Age.	Height.					
	Maryland. ²			Louisiana. ³		
	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.
<i>Years.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
10.....	26	11	3	24	17	9
20.....	44	22	7	45	31	17
30.....	58	33	12	61	43	26
40.....	71	46	18	75	54	34
50.....	82	60	25	86	65	43
60.....	91	72	32	97	74	51
70.....	99	81	39	.....	83	60
80.....	106	88	44	.....	92	69
90.....	113	95	50	.....	101	78
100.....	119	101	54	.....	109	86

¹ Acknowledgment is made to Mr. George E. Watson, secretary of the Southern Cypress Manufacturers' Association, and various operating members of the association, for assistance rendered the writer in the collection of field data used in the bulletin.

² Based on sectional age counts of 68 trees, also total heights of 221 additional trees 6 to 103 years old.

³ Based on sectional age counts of 42 trees 38 to 89 years old.



AVERAGE SECOND GROWTH CYPRESS ON CUT-OVER LANDS. (GRAND RIVER BASIN, LA.)
Height, 71 feet; diameter (breasthigh), 13 inches; age, 48 years. Compare with virgin forest growth, Plate X, figure 1.

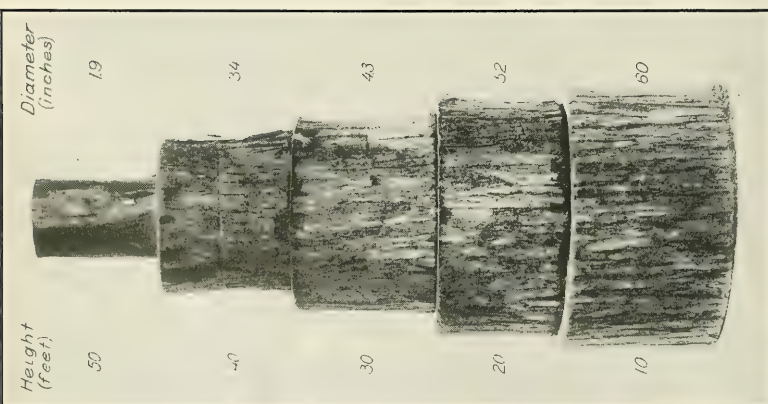


FIG. 1.—AVERAGE YOUNG POLE CYPRESS GROWN IN VIRGIN FOREST.

Height, 62 feet; diameter (breasthigh), 8 inches; age, 46 years. Compare with second-growth cypress in Plate IX.

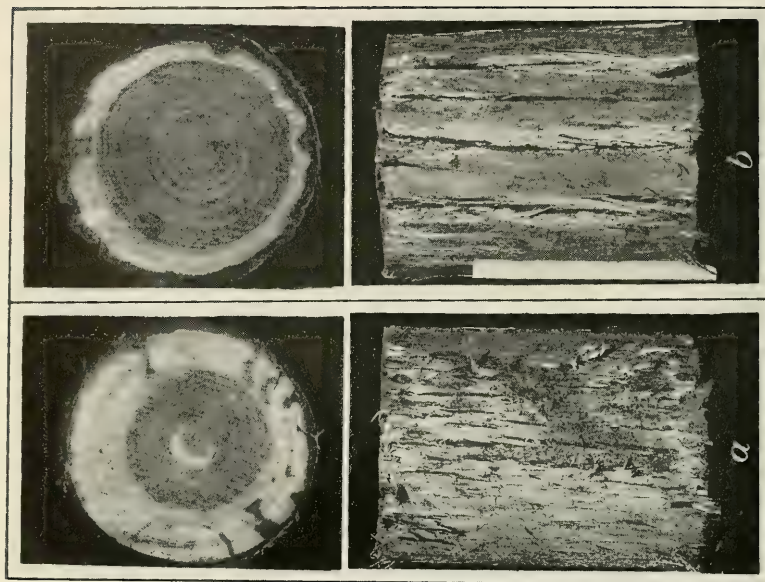


FIG. 2.—BOTANICAL FORMS OF CYPRESS. (ST. JOHNS RIVER, FLA.)

a. Thin, brown bark and wide sapwood.
b. Thick, reddish bark, narrow sapwood and darker heartwood.

TABLE 8.—*Height of cypress growing in virgin stands, on the basis of age.*

Age.	Height.					
	Louisiana. ¹			Maryland. ²		
	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.
Years.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
10	25	15	5	16	11	4
20	49	30	10	33	23	8
30	65	40	15	48	35	12
40	74	47	20	62	46	17
50	80	53	25	74	56	22
60	85	58	30	83	65	29
70	90	63	35	90	73	35
80	93	67	40	97	80	42
90	96	70	44	103	86	48
100	99	74	49	108	91	53
110	101	77	53	113	96	58
120	103	81	58	118	100	62
130	105	84	62	122	104	66
140	107	87	66	125	107	70
150	108	89	70	129	110	74
160	109	91	73	132	113	77
170	110	93	76	136	116	79
180	111	95	79	139	118	82
190	112	97	81	142	121	85
200	113	98	83	146	124	87
210	114	99	84			
220	115	100	85			
230	115	101	86			
240	116	102	87			
250	117	103	88			

¹ Based on sectional age counts of 73 trees, 88 to 793 years old.² Based on sectional age counts on 22 trees, also total heights of 77 additional trees, 104 to 199 years old.

Cypress, like shortleaf and loblolly pines, culminates its rate of height growth usually in the second decade. Both of the pines, however, make a somewhat faster average annual growth than cypress. Second-growth cypress in Louisiana, exposed freely to overhead light, increase about 12 feet in the period between the ages of 20 and 30 years, while loblolly pine in North Carolina averages about 15 feet. In virgin stands the young trees grow up under more or less overhead shade due to the height and density of the cypress canopy, with the result of a decrease in growth. The growth by decades of cypress and loblolly pine is shown in Table 9.

TABLE 9.—*Height growth by decades for virgin and second-growth cypress in Louisiana¹ and virgin loblolly pine in North Carolina.²*

Species.	Decade beginning at age of—												
	20	30	40	50	60	70	80	90	100	110	120	130	140
	Height growth—feet.												
Virgin cypress.....	10	7	6	5	5	4	4	4	4	4	3	3	2
Second-growth cypress.....	12	11	11	9	9	9	9	8	(3)	(3)	(3)	(3)	(3)
Loblolly pine.....	15	13	10	9	7	6	5	4	3	3	2	2	2

¹ See Tables 6, 7, and 8.² Ashe, W. W., Loblolly pine study in North Carolina. Based upon about 1,000 trees.³ Figures not available.

The slower initial but more sustained rate of growth in cypress as compared with the faster initial growth but earlier decline in rate in loblolly pine is clearly seen in Table 9. It is quite notable that between the ages of 90 and 100 years the two species are growing in height at about the same rate, and afterwards cypress leads until about 150 years. In the second century, loblolly pine averages 20 feet and cypress 24 feet of growth in height. The region of greatest height for cypress is apparently in South Carolina and Georgia, where also probably occurs the largest average diameter. Stands frequently average 125 feet in height, and individual trees 140 feet high are scattered through the forest.

GROWTH IN DIAMETER.

Cypress is popularly considered a tree of very slow growth. This belief is due to the slow rate of growth of virgin timber, and is justified by measurements shown in Table 12. In regard to second-growth or open-grown cypress the case is very different. The diameter growth of the latter, shown in Table 11, compares well with that of the more important southern hardwoods and some of the pines.

Annual increase in diameter is markedly irregular in individuals from year to year, or in successive periods of years. Cypress is extremely persistent in diameter growth. Old hollow trees grow steadily at about the same annual rate for several centuries.¹ In this character, cypress closely resembles the redwoods of the western United States, in contrast with the southern pines, which at a very much earlier age fall off in the rate of their diameter increment. Table 10 shows that there is little variation during the first 200 years in rate of growth at breastheight of virgin cypress in Louisiana. Second-growth in Maryland, between 60 and 100 years, is very uniform at a rate of 1 inch in every 5 years.

Measurements on trees up to 800 and 900 years old show the beginning of a marked decline in diameter growth at points varying from 350 to 500 years, and occasionally not until the tree reaches the age of 600 years.

¹ Annual rings of growth on the swell-butted stump of cypress are very faintly marked lines often difficult to distinguish. False rings consisting of well-marked brown bands or stains are numerous, especially in early life, and easily mistaken for true rings unless close attention is given.

TABLE 10.—*Diameter of a 900-year-old cypress at the end of successive 50-year periods (Louisiana).¹*

Age.	Diameter.	Time required to grow 1 inch.	Age.	Diameter.	Time required to grow 1 inch.
<i>Years.</i>	<i>Inches.</i>	<i>Years.</i>	<i>Years.</i>	<i>Inches.</i>	<i>Years.</i>
50	6.0	8.3	500	65.8	8.6
100	12.5	7.7	550	72.5	7.5
150	18.5	8.3	600	79.0	7.7
200	25.9	6.8	650	84.2	9.6
250	32.4	7.7	700	87.8	13.9
300	39.4	7.1	750	91.2	14.7
350	46.1	7.5	800	94.1	17.2
400	54.0	6.3	850	98.6	11.1
450	60.0	8.3	900	103.2	10.9

¹ Measurements at breastheight on the stump, inside bark, taken along an average radius, doubled to obtain diameters. Lake Maurepas region, Livingston Parish, La. Total age of tree, 915 years.

TABLE 11.—*Diameter increase of second-growth cypress in Maryland, based on age.¹*

Age.	Diameter breast high.			Diameter outside bark at 20 feet above ground.		
	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.
<i>Years.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
10	5.1	1.1	0.4	3.5	2.1	0.2
20	10.0	3.5	1.2	7.8	4.5	1.0
30	14.2	6.2	2.2	11.2	6.7	1.9
40	17.6	8.7	3.3	13.8	8.7	3.0
50	20.5	11.1	4.4	15.6	10.4	4.1
60	23.2	13.3	5.8	16.9	12.1	5.4
70	25.8	15.3	7.2	17.9	13.6	6.9
80	28.6	17.3	8.9	18.9	15.0	8.6
90	30.8	19.3	11.0	19.8	16.1	10.3
100	33.3	21.3	13.2	20.6		

¹ Based on decade measurements on 237 stumps of trees 7 to 101 years old.

Because of the enlarged base of cypress in very wet soils the breast-high diameter (4.5 feet above the ground) is not a good index to the volume of the tree trunk, except after middle life. At the height of about 20 feet (about the top of the first 16-foot log) the character of diameter growth is comparable with that at breast-height of common upland trees and serves well as an index to the contents of the whole tree.¹ Table 11 indicates that a butt log 8 inches at the top end² can be grown in about 46 years, a 12-inch log in 70 years, and a 16-inch log in 100 years.

The trees of the virgin forest started, as a rule, under a moderate or light overhead shade, and their growth was therefore slower than that of young trees either in natural stands in logged forest areas or in stands thinned under intensive forest management.

¹ Diameter inside bark, allowing $\frac{1}{2}$ inch for width of bark.

² The large basal swell and close utilization in milling give overruns estimated at 25 to 40 per cent, and more in young and deeply submerged timber.

TABLE 12.—*Diameter of virgin cypress in Louisiana, based on age.*¹

Age.	Diameter breast high.	Diameter outside bark 20 feet from ground.	Age.	Diameter breast high.	Diameter outside bark 20 feet from ground.
<i>Years.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Years.</i>	<i>Inches.</i>	<i>Inches.</i>
10	0.8	-----	110	12.8	7.3
20	2.3	-----	120	13.7	8.0
30	3.7	0.6	130	14.6	8.7
40	5.0	1.5	140	15.5	9.4
50	6.2	2.4	150	16.3	10.0
60	7.5	3.2	160	17.1	10.6
70	8.6	4.1	170	17.8	11.2
80	9.7	4.9	180	18.6	11.8
90	10.8	5.7	190	19.3	12.3
100	11.8	6.5	200	20.0	12.8

¹ Based on decade measurements on 68 stumps, 92 to 791 years old (average, 263 years).

There is good evidence based upon the measurement of a large number of trees that diameter growth of cypress under similar local situations over its northern range, for example Missouri and Maryland, is practically the same as throughout the Southern States. In strongly acid and shallow soil, where growth is exceedingly slow, trees from 8 to 10 inches at breastheight may be from 180 to 240 years old.

GROWTH IN VOLUME.

The combined growth in height and diameter determines the growth of a tree in volume. Commercially it is very desirable that the volume increment be made by trees as cylindrical in form and free of branches as possible.

Large cypress trees, measuring from 5 to 8 feet in diameter, often contain from 5,000 to 10,000 board feet of merchantable lumber. A 4-log tree in the Okefinokee Swamp scaled 6,875 board feet,¹ a 5-log tree scaled 12,025 feet, and 3 logs from one tree cut 9,900 feet mill scale. A 5-log tree on the St. Johns River in Florida cut out 9,600 feet. There is record on the Santee River, South Carolina, of one 22-foot log scaling 4,000 board feet. In stands running from 12 to 16 inches in diameter, as many as 10 to 15 logs are required for a thousand board feet. The log run probably averages now mostly between 3 and 5 logs per thousand,² although the size of the cypress logged in the same region varies greatly. In 12 consecutive days in 1913 one large company in southern Louisiana, which is clean-cutting a typical deep cypress swamp, hauled out 2,742,000 feet, averaging a little less than 5 logs per thousand feet, or about 208 feet per log.

Tables 16 and 17, given in discussing the value of the timber crop, show the relation between increase in diameter and volume. Volume

¹ Doyle scale.

² In 1897 in a typical logging operation, Roth found an average of 10,000 logs to run about 300 feet, or 3½ logs to the thousand board feet.

tables showing cubic volume based upon the diameter of the tree measured outside the bark at the middle point of the trunk ("Schiffel's" method) are being increasingly used. Strangely, this middle-point method when applied to cypress gives very accurate results compared with the actual log volume.¹ Forty trees from 11 to 56 inches in diameter showed an error of only 0.2 per cent.

TAPER.

The taper of cypress above the basal swell is considerable in very young and in isolated trees, moderate later in life, and, in forest stands, very slight at maturity. The amount and variation in the basal swell have been discussed on page 24. One tree on the Santee River, South Carolina, tapered 5 inches, or from 54 to 49 inches, in a cut of four 16-foot logs. A taper of 2 inches to each 16-foot log prevails with singular uniformity in middle life, and may be accepted as an approximate rule. Table 22 in the Appendix shows the diameters at various heights above the ground up to 5 feet. The actual taper of cypress is usually greatly overestimated because of the striking comparison with the enlarged base. Judging from all measurements, the stem of cypress above the basal swell does not differ greatly in its taper from that of the southern pines.

EFFECT OF DRAINAGE UPON CYPRESS GROWTH.

Although essentially a silvical question, the effect of draining upon the growth of cypress is of interest in a general discussion of swamp-land reclamation. While there is insufficient direct evidence and no experimental data in regard to the effect of heavy draining upon the growth of cypress, certain conclusions may be stated tentatively.

A sudden and decided lowering in the permanent water level is very likely to produce injurious results to tree growth by the disturbance in the former equilibrium between the root system and water supply. Cypress is believed to possess to a large degree the power of adjusting its root system to meet its requirements for growth under a gradual reduction in the soil water. A mature cypress stand at Walls, Miss., was in a healthy condition when cut in 1913, 15 years after the deep but gradual draining of the slough in which it grew.² Mr. H. B. Hewes,³ Jeanerette, La., however, states that cypress on lands in Avoyelles Parish, La., previously reclaimed by levees along the Atchafalaya River, when examined showed considerable decay at the bases of the trees. A moderate amount of drainage will undoubtedly be as beneficial to cypress as

¹ Tables 18 to 21 in the Appendix show the volumes of cypress in Maryland, South Carolina, and Louisiana.

² Walls, W. R., Civil Engineer, Walls, Miss.

³ Chairman of a special committee of the Southern Cypress Manufacturers' Association, New Orleans, La., for studying the utilization of cut-over lands.

to various other species when growing in an excess of water. Temporary effects must always be distinguished from permanent injury or benefit, and further detailed observations before and at successive periods following the drainage will be necessary in the case of cypress before the effects can be completely stated.

CYPRESS STANDS.

Cypress occurs both in pure stands and in mixture with various hardwoods. It may be said to be a tree of even-aged groups within all-aged stands. This is due to the very intimate relation between water level and successful seed germination mentioned in the discussion of reproduction and the transitory character of swamps as compared with dry-land farms. In considering trees in the aggregate, or stands, it is essential to know (1) the composition of the stand, and (2) the amount of timber produced per acre under different conditions, or the yield.

PURE STANDS.

Cypress forms practically pure stands in the back swamps, oxbows, or cut-offs, and the deep swampy portions of alluvial river flood plains. These places are commonly known as "sloughs" and the bodies of pure cypress as "cypress brakes." In the large inland swamps of the Atlantic Coastal Plain pure stands of cypress occur in the form of concentric rings of progressive-age classes around the bodies of open water. The home of the pure or nearly pure cypress forests of large extent is in Louisiana and Florida, in deep swamps overflowed for a portion of the year. Pure stands of cypress, although widely distributed, are local rather than regional in their occurrence. Cypress is characteristically the dominant tree wherever it occurs. The number of trees per acre and the amount of timber in pure stands is discussed on page 48, under the subject of "Yields."

MIXED STANDS.

The home of the mixed cypress and hardwood forest is on the undulating portions of swamps, known as glades. These occupy an intermediate position between the ridge on one side and the slough or back swamp on the other (see figs. 2 and 3, p. 22). In wet or swampy situations in the Southern States slight differences in the lay of the land, with accompanying differences in moisture content, cause a wide diversity in the character of the forest stand. The glade formation is the prevailing type over much of the southern swamp lands. During periods of high water the glades are overflowed for several weeks at a time, but become partially drained after the floods disappear. The average water table is usually from 1 to 2 feet below the surface. Over the glades cypress is supreme in all the depressions and water holes, and occurs both in groups and in pure stands.

TABLE 13.—Composition of typical mixed cypress and hardwood stands in Maryland and South Carolina.

Species.	Trees per acre and relative importance in the stand.			
	Maryland (average of 103 acres).		South Carolina (average of 599 acres).	
	Trees.	Per cent.	Trees.	Per cent.
Cypress.....	38.92	23.53	58.14	45.19
Black gum.....	35.46	21.44	23.99	18.65
Red maple.....	31.67	19.15	5.59	4.34
Red gum.....	22.01	13.31	3.33	2.59
Ash.....	13.89	8.40	.90	.70
Elm.....	7.76	4.69	.23	.18
Cottonwood.....	6.18	3.73		
Black oak.....	1.83	1.11	2.29	1.78
White oak.....	2.22	1.34	.40	.31
Yellow poplar.....	.01	.01	1.08	.84
Hickory.....	.01	.01	.18	.14
Beech.....	1.06	.64	.14	.11
Holly.....	1.71	1.03	.05	.04
Sweet magnolia.....	.56	.34	.04	.03
Willow.....	.52	.31		
Persimmon.....	.13	.08		
River birch.....	.58	.35		
Longleaf pine.....			.55	.43
Loblolly pine.....	.88	.53	31.45	24.45
Red cedar.....			.28	.22
Total.....	165.40	100.00	123.64	100.00

Cypress is a tree of relatively few associates. These are all hardwoods, with the exception of southern white cedar. Preeminent among all associated species in the deeper and fresher waters from Virginia to Texas is tupelo gum.¹

In the inland, poorly drained, nonalluvial and peaty swamps over the Atlantic Coastal Plain black gum holds nearly the same rank. Other species associated with cypress are water ash, water locust, white or swamp bay, and red bay on the Atlantic coast; these and the cabbage palmetto, willow oak, and water oak in Florida, and in Louisiana the willows and tupelo gum.

On the higher and drier portions of the glades in southern Louisiana, where cypress is not reproductive, the heavy forest is com-

¹ Common and botanical names of species mentioned in this and other paragraphs of this bulletin:

Tupelo gum (<i>Nyssa aquatica</i> Linn.).	Florida ash (<i>Fraxinus floridana</i> Sarg.).
Black gum (<i>Nyssa sylvatica</i> Marsh.).	Green ash (<i>Fraxinus lanceolata</i> Borkh.).
Water gum (<i>Nyssa biflora</i> Malt.).	White ash (<i>Fraxinus americana</i> Linn.).
Red gum (<i>Liquidambar styraciflua</i> Linn.).	Hackberry (<i>Celtis occidentalis</i> Linn.).
Water oak (<i>Quercus nigra</i> Linn.).	Honey locust (<i>Gleditsia triacanthus</i> Linn.).
Overcup oak (<i>Quercus lyrata</i> Walt.).	Water locust (<i>Gleditsia aquatica</i> Marsh.).
Willow oak (<i>Quercus phellos</i> Linn.).	White elm (<i>Ulmus americana</i> Linn.).
Red oak (<i>Quercus rubra</i> Linn.).	Shipping elm (<i>Ulmus fulva</i> Michx.).
Swamp white oak (<i>Quercus platanooides</i> Sudw.).	White cedar (<i>Chamaecyparis thyoides</i> Britt.).
White bay (<i>Magnolia glauca</i> Linn.).	Slash pine (<i>Pinus caribæa</i> Morelet).
Red bay (<i>Gordonia lasiantha</i> Ell.).	Spruce pine (<i>Pinus glabra</i> Walt.).
Cabbage palmetto (<i>Sabal palmetto</i> Roem.).	Pond pine (<i>Pinus serotina</i> Michx.).
Red maple (<i>Acer rubrum</i> Linn.).	Longleaf pine (<i>Pinus palustris</i> Mill.).
Cottonwood (<i>Populus deltoides</i> Marsh.).	Loblolly pine (<i>Pinus taeda</i> Linn.).
Water ash (<i>Fraxinus caroliniana</i> Mill.).	Shortleaf pine (<i>Pinus echinata</i> Mill.).

posed chiefly of red maple, water oak, red oak, ash, honey locust, hackberry, and red gum, in association with mature cypress. In southeastern Mississippi a tract of 807 acres, mostly overflowed in winter and spring, contains the following hardwood associates of cypress, stated in the order of their relative importance: Ash, white and red elm, red maple, red and tupelo gums, various oaks, hackberry, hickory, and cottonwood. In all of these higher glades groups of pure cypress occur in the depressions, and elsewhere older trees are scattered in mixture with the hardwoods. The gradual shifting of the main currents during floods produces changes in the location and height of the ridges in the glades, together with corresponding changes in the composition of the forest due to the different moisture requirements of the various species.

Over the southern Atlantic Coastal Plain, mature red gum, overcup oak, water elm, water and Florida ash, and bitternut hickory occupy the low ridges in the large river swamps. Tupelo gum, water ash, and small amounts of cottonwood and water locust, along with cypress, stand in water during much of the year. Two other types in this region are found in the nonalluvial Dismal and Okefinokee Swamps, and the mixed white cedar and cypress swamps from Virginia to Florida. The Okefinokee forest is made up essentially of heavy stands of pure cypress over the younger and middle-aged portions, and a dense hardwood forest with scattering veteran cypress over the older-aged portions of the swamp (fig. 3). Among the hardwoods, black gum leads, and there is much white bay, red bay, red maple, and willow and water oak. The more valuable yellow poplar, red gum, and ash, if present, are in very small quantities. The white cedar peat swamps contain varying mixtures of cypress and white cedar, with pond and slash pine around the borders.

Along the swamp borders cypress closely meets the many conifers and hardwoods which compose the upland forests of the Southeast. The small cypress ponds of the flat, pine-barren type contain small amounts of water gum, a dwarf form of the black gum, while pond, spruce, and slash pines are encroaching actively from the outside as the ponds become drier through the destruction of the surrounding pine forest.

YIELD.

In pure stands and in the better cypress regions of the Southern States, particularly Louisiana and Florida, virgin cypress yields of 8,000 to 14,000 board feet per acre are not uncommon over tracts several hundred miles in extent. The size of the trees and density, or number of trees per acre, is very irregular. In a few localities manufacturers are now cutting bodies of pure cypress containing a total of up to 100,000,000 feet, which will average more than 20,000 feet per acre.

In many important timber species a commonly accepted standard of the "cut" of average stands becomes well established. Thus, in the better cypress regions, a cut of 12,000 to 15,000 feet per acre is a recognized standard over large areas. One fully stocked cypress stand of mixed ages along the Apalachicola River in Florida, ranging from large mature trees 40 inches in diameter down to 10-inch trees, contained an average of 112 cypresses and 48 hardwoods (chiefly tupelo gum), or a total of 160 trees per acre. The indicated yield, by Doyle rule (Appendix, Table 20), after allowing 20 per cent for defect, was 43,600 feet of cypress per acre. In Louisiana, an average yield of 45,000 feet per acre is limited to relatively small areas of timber. Maximum yields of virgin cypress of from 50,000 to 60,000 per acre occur on small tracts or cypress "brakes" in the most favorable situations. Stands are reported as having cut 100,000 feet on selected acres. One acre on Grand River, Louisiana, was estimated by an experienced lumberman to contain 127,000 feet of merchantable cypress.¹

The best cut in several years in a representative region in the Grand River basin in southern Louisiana was an average of 35,000 feet per acre from a 40-acre tract, or a total of 1,400,000 board feet. During a period of 50 years or more early float logging culled out many individual cypress trees, mostly in localities subject to periodic high water and near main water courses. The average yield per acre, also the average grade, increases notably in many logging operations upon working away from the water fronts farther back into the deep swamps.

A 30-year old stand of cypress in an old cutting in Louisiana, where sufficient seed trees had been left, contained an average of 340 trees per acre about 5 inches in diameter at breastheight. Mature cypress stands, from 250 to 350 years old and well stocked, usually contain from 40 to 60 trees per acre. In more scattered and typical stands, in some regions, the trees from 12 to 20 inches in diameter may average about 40 trees per acre, older timber from 18 to 24 inches in diameter about 30 trees per acre, and stands of large trees from 2 to 4 feet in diameter mostly from 15 to 20 trees per acre over large areas.

The number of trees per acre and the size of the individual trees both show great irregularity in tracts as small as 40 acres. Cypress occurs mostly in all-aged stands made up of several even-aged classes. As virgin timber becomes more scarce and second-growth cypress more valuable and important there will be need for yield tables of fully stocked pure stands for use in calculating future yields and returns from management.

¹ Capt. E. T. Forgey, Morgan, La.

FOREST MANAGEMENT.

The possibilities of cypress as a tree of large commercial importance under forest management in the future depends very largely on the extent to which denuded swamp lands can be utilized. Obviously, these lands if drained would be very valuable for agricultural use. Therefore a discussion of the probability of the lands being successfully adapted to agriculture is a prerequisite to the consideration of the advantages, aim, and methods of forest management.

FUTURE UTILIZATION OF CYPRESS LANDS.

AREA AND OWNERSHIP OF PERMANENT SWAMP LANDS.

Of the various classes of swamp lands requiring drainage to fit them for profitable cultivation, cypress occupies the extreme class known as "permanent" swamps. These lands are never fit for cultivation in their natural state, even during the most favorable seasons, and those portions that may be grazed afford forage of very uncertain value. So far as revenue is concerned, the lands may be considered as unproductive, except for the growth of timber. The total area of such permanent swamp land in 10 of the States where cypress occurs is approximately 42,440,000 acres, distributed as shown in Table 14:

TABLE 14.—*Permanent swamp area in 10 of the most important cypress producing States.*¹

State.	Area.	State.	Area.
	<i>Acres.</i>		<i>Acres.</i>
Florida.....	18,000,000	Georgia.....	1,000,000
Louisiana.....	9,000,000	Missouri.....	1,000,000
Arkansas.....	5,200,000	Alabama.....	900,000
Mississippi.....	3,000,000	Virginia.....	600,000
South Carolina.....	1,500,000		
Texas.....	1,240,000	Total.....	² 42,440,000
North Carolina.....	1,000,000		

¹ U. S. Senate Document 443, Sixtieth Congress, first session, "Swamp Lands of the United States," prepared by the Office of Experiment Stations, Department of Agriculture.

² The permanent swamp lands of Delaware, Maryland, Tennessee, Kentucky, Illinois, and Indiana where cypress occurs contain about 1,000,000 acres.

It is interesting to note that the area shown in Table 14, much of which is natural cypress land,¹ comprises about 80 per cent of the lands classed as "permanent swamp" and 49 per cent of the entire wet land of all classes in the United States.

All the more valuable southern swamp lands have passed into private ownership. By act of Congress, September 28, 1850, and subsequent enactments, all swamp lands were granted to the various States in which they occurred. For the most part these were in turn sold by the States to private owners. Federal swamp land, unsurveyed and therefore unclaimed by the States, is of exceedingly small area.

¹ In Florida a larger proportion of the area included is nonforested or everglade land.

VALUE OF CUT-OVER SWAMP LAND.

Swamp lands with all the cypress cut out are of rather indefinite value. They are considered mostly unproductive at present and are being held chiefly for their potential value for agriculture after draining and clearing. The scattering stands of associated tupelo gum left on the larger river deltas and narrower stream bottoms have very small stumpage value, while in the slightly higher undulating swamps the oak, ash, and other hardwoods, if of good development, are generally being logged along with the cypress.

In the Mississippi Valley, where a large percentage of the 16,000,000 acres of more or less reclaimed swamp land lies, a figure of \$2 to \$2.50 perhaps represents fairly well the claimed or speculative value of cut-over cypress swamp lands. Deep sloughs and lagoons fall far below these figures, while "ridges" and higher swamps exceed them in their actual value. A clear distinction should be drawn between *stump* land and *open marsh* land, both of which may be permanent swamp. The equalized average value of denuded cypress lands in Louisiana agreed upon by the State board of equalization for 1913 was \$1.50 per acre, while denuded pine land was \$2.13, denuded hardwood land \$2.15, fresh-water marsh \$0.94 to \$1.08, and salt-water marsh-land from \$0.49 to \$0.88 per acre. Some large accessible tracts in Louisiana of black calcareous soil and open marsh are held as high as \$10 to \$15 per acre. Largely because of the sterility of the acid soils without the addition of lime, and the high cost of clearing the land of the mass of stumps with large heavy roots, the "ponds" and large inland swamps over the lower Atlantic coastal region are at present considered of low nominal value.

COST OF DRAINING AND CLEARING.

The reclaiming of permanent swamp soil for cultivation requires (1) the improvement of natural drainage channels and construction of main ditches or canals—such public drains are made through the cooperation of owners under the provision of State drainage laws; (2) the construction of branches and laterals by the landowners; and (3) the removal of natural vegetation, including stumps. The order in which the various classes of permanent swamp lands will come under reclamation will obviously be governed by the question of cost and relative soil fertility. Open grassy swamps of which there is a large area, will undoubtedly be chosen first in drainage plans, the glades or hardwood ridges naturally drained during a considerable part of the year will follow, and then the *deep* swamps, where cypress finds its characteristic home.

The cost of complete reclamation of stump lands will be very much greater than the average for all lands classed as permanent swamp. The Office of Experiment Stations of the Department of Agriculture

estimates \$17 as the average cost per acre of draining permanent swamps.¹ This figure includes public drainage, private drains, and clearing the land for cultivation. Where the original surface is covered with stumps, the additional expense of clearing cut-over cypress land in Louisiana has been found to range from \$30 to as high as \$100 an acre, depending upon the character of growth.² This makes a total expense ranging from \$47 to \$117, or an average of \$82 per acre, for reclamation. If the present value of reclaimed swamp lands and the demand for them is considered, this expense undoubtedly is not justified.

In large drainage projects plans seldom include the reclamation of all the land within the district to be drained. The cost of such work, under present economic conditions, would be altogether prohibitive. Doubtless in some future period the rise of land values will warrant very costly drainage systems. Those cypress lands, which may reasonably be expected to remain to a large degree undrained for many decades, include (1) sloughs and lagoons in otherwise undulating swamp and overflowed land, (2) strips between levees and the normal river channel, (3) entire tracts of deep swamps where cypress grows in pure stands because the land is too wet for other species, (4) narrow marginal swamps along rivers subject to periods of high overflows, and (5) countless small inland "ponds" and dead swamps in flat, poorly drained regions.

VALUE OF RECLAIMED SWAMP LANDS.

The market value of reclaimed swamp lands is generally from \$15 to \$25 net over and above the cost of the drainage and other work.¹ An expense of \$12 an acre for draining, \$30 to \$100 for clearing, and an initial land value of say \$1, plus the operator's profit of \$15 to \$25, give final values to reclaimed cypress lands ranging from \$60 to \$140 an acre. This may profitably be compared with the expense of reclaiming wet prairie land, which will include approximately \$17 for draining and clearing,¹ \$5 to \$15 for the land, and the operator's profit of \$15 to \$25, or a total of \$35 to \$60. The latter closely approximates current local sale values of drained lands in good condition to produce agricultural crops in the lower Mississippi Valley. Close to good markets, values run above \$100 an acre, for intensive use.

This high value of reclaimed prairie land, over and above the cost estimates for an efficient drainage system by conservative engineers, allures capital strongly toward utilizing rich swamp for agriculture.

¹ U. S. Senate Document 443, 60th Cong., 1st sess. Prepared by Office of Experiment Stations, U. S. Department of Agriculture.

² U. S. Department of Agriculture, Bul. 71, Office Experiment Stations (Professional Paper), "The Wet Lands of Louisiana and their Drainage."

In the Mississippi Valley, with an overflow area of 50 to 75 miles in width affording millions of acres of very productive soil, this situation is especially emphasized. By comparison, timber growing as an investment has little to offer. It must not be forgotten, however, that a sharp distinction should be drawn between open lands and those covered with a forest of large trees. The perfection of dredging by modern machinery and the possibilities in the control of waters as demonstrated in the Panama Canal and other engineering works, are convincing evidences of the probability of success in the reclaiming of overflow and swamp soils, and have at times led to excessive speculation over tracts promising ready drainage.

In the flush of logging virgin stands of cypress, very little serious consideration has commonly been given to the question of the future use for which the land is best adapted. The largest cypress manufacturers' association in Louisiana has, however, given definite consideration and study to this problem along with the advance of lumbering. Tentatively, their policy is to clean cut cypress lands, having in view their probable early drainage and value for agricultural development, in spite of the high expense of removing the stumps and clearing the lands for cultivation. Consideration of the combined expense of draining and clearing the land, and the distance to markets, will serve to indicate whether or not the investment is a paying one.

It is important in this connection to distinguish clearly between the rich, deep alluvial lands which lie in continuous bodies of extensive area and the numerous small, more or less isolated cypress tracts where drainage features are very different. As a result of large profits realized in the past from draining the open savannas or grassy swamp lands, there is undoubtedly a strong tendency toward a too optimistic view of the early reclamation of deep cypress swamp lands. A large number of operators, convinced that reclamation is certain to be profitable, have decided in favor of taking every cypress tree of possible commercial value and leaving none for future returns.

In reclaiming swamps which are the result of river inundation, the first step of importance is to reduce the amount of overflow. This suggests measures for protecting watersheds against floods, both in the interest of the swamp-drainage system and the preservation of our navigable-stream channels. The long period of time necessary must not be overlooked, since plans for permanent reclamation call for an orderly progression of the work in accordance with the need for the land, market conditions, and transportation facilities. The information available regarding the rate of growth of second-growth cypress trees and stands and the effect of drainage upon growth (see pp. 39 to 46) will be helpful to the owner of cypress land in arriving broadly at conclusions regarding its comparative future value for agriculture and timber production.

AIM AND METHOD OF FOREST MANAGEMENT.

Forest management is not nearly so well understood as farm management, although the object of each is the same; namely, to secure the highest financial returns from the class of land involved. With the cutting of the virgin stands, timberlands become available for further productive use for the purpose to which they are best adapted from a financial standpoint. Many tracts of forest, particularly in the Northeastern States, are being handled with a view of securing the largest continuous yield of timber of the most valuable species. This is the aim of forest management.

To cut the mature timber in such a manner as to secure its fullest utilization, and, following logging, to obtain complete stands of young seedlings as the basis for the next crop, are the chief objects to be attained by properly handling forests. In places where natural reproduction fails, the stand may be filled out by sowing seed or planting seedlings raised in nursery beds. Protection of the growing trees against various forms of injury and further assistance of the trees in their growth by proper thinning are important steps in attaining the desired end.

Forest management of cypress deals with the proper handling of present supplies rather than with the extension of the species on a general scale. For various reasons cypress does not promise to be one of the main contributors of the country's future timber supply. Forest management of cypress in the future will consist chiefly of (1) the conservative cutting and close utilization in logging of the present virgin stand, (2) in many cases the retention and protection of the younger growing timber, and (3) manufacturing so as to secure the largest production of the best grades.

PROFITABLENESS OF FOREST MANAGEMENT.

In logging virgin cypress timber, the question inevitably arises whether it is profitable to leave the younger portions of the stand for a second cut. For example, if a cypress stand cut clean at the present time will yield \$10,000 net profit, will it pay the owner to take four-fifths of the merchantable timber at the present time, consisting of the larger classes and yielding a net profit of \$9,000, and postpone the returns on \$1,000¹ until the time of a second cut?

In favor of holding a portion of the timber for the second cut are the following: The increased local demand for timber resulting from the establishment of new industries in the South, the faster growth of the timber left standing from the first cutting, and the excessive cost of clearing and draining deep swamp land covered with stumps and roots. Under these conditions it will undoubtedly in many instances be good business to leave cypress trees below a specified diameter limit,

¹ Small sizes are expensive to log and yield little if any net profit.

for example, 18 to 24 inches on the stump, where present cutting takes everything down as low as 12 to 14 inches. Natural conditions favorable to a deferred second cut may be found (1) in stands of mixed ages with good representation of younger groups of cypress; (2) where logging will be repeated in a decade or two in order to remove good stands of hardwoods not at present merchantable; (3) where the fixed cost of logging is low, as in float logging; and (4) in the present very low producing power of the land for any other purpose than timber growing.

There are several classes of cypress lands (see pp. 21-22) which are not likely to be reclaimed and put under cultivation for many decades, if ever. These situations are mostly subject to deep overflows and thus permit float logging, which is the least expensive and the most practical form of follow-up logging for second-growth cypress lands in the future. The associated "ridges," or better drained portions of the swamp, characterized usually by mixed hardwoods with scattering mature cypress, in the orderly progression of swamp reclamation will earlier come under drainage and farm management. This distinction between the relative heights of different levels of the swamp and their respective future uses, it is believed, is commonly given too little consideration in connection both with plans for reclamation projects and with the conservative cutting and management of cypress stands.

In many swamps good stands of the more valuable hardwoods have been left, such as oaks, ash, and gums, which will be removed in the course of from 10 to 25 years. Many large operators intend to go back later over the old cutting areas and log timber which was unmerchantable at the time of the first cutting. Here the practice of clean cutting of cypress down to include the young vigorous trees would be, from a purely financial standpoint, unquestionably a mistake. These trees are rapidly increasing in size and should be left for a later logging. Float logging, where the investment and cost of logging are low, permits of conservative cutting and an approach to a sustained yield of timber by selecting the trees on the basis of a minimum diameter limit.

In favor of clear cutting is the fact that there are a large number of lumbering plants in the South which promise from 6 to 8 per cent returns on safe investments. In comparison with these opportunities, the uncertainty of the lumber market 20 or 40 years hence discourages delay in harvesting the available crop, especially if present owners bear in mind the qualifications of Pacific coast lumber for competition with cypress and the extent to which its use will increase in the eastern market as a result of the opening of the Panama Canal and other causes. The increasing use of various substitutes for wood is another factor to be taken into consideration.

Whether forest management will prove profitable and is therefore advisable depends largely upon (1) the rate of growth and various other characteristics of the species; (2) capital represented by the land and growing timber; (3) cost of establishing, protecting, thinning, and other operations in the stand; and (4) the final money values of the timber crops produced.

Clear cutting is generally advisable where the land now commands or promises soon to command, a high value for farm use, where the stand of cypress is practically pure and mostly mature without clumps of young growth, and where logging costs are very high.

ADAPTABILITY OF CYPRESS TO MANAGEMENT.

The leading characteristics of cypress which bear upon its suitability for management are:

(1) Cypress inhabits permanent swamps much too wet for agriculture and most other uses, except when drained at a large and sometimes prohibitive cost. It is adapted and valuable, therefore, for utilizing large areas of otherwise unproductive swamp land.

(2) In exposures open to light, the rate of growth greatly exceeds that of virgin stands, and on similar sites is comparable with the growth of red gum, ash, and other more common hardwoods; crowded stands thin themselves slowly and growth is moderate unless helped by thinning for pole, tie, or other classes of small timber.

(3) It is inherently a vigorous tree with few enemies, is readily grown from seed, and, judging by experience and observation, may be planted out with good results when 1 or 2 years old.

(4) Cypress is well adapted for growing in pure, even-aged stands. This form of stand is economically favorable because of the difficulties and high expense of logging, except where water transportation is available.

(5) Although cypress makes its best growth on deep, well drained, fresh or moist loamy soils, on account of inherent restrictions it practically never reproduces itself there. It reproduces and permanently maintains its position as the dominant tree of the stand only in extremely wet situations. Since the higher swamp areas are more easily drained and will be the first to be utilized for farm crops, the "ridge type" of hardwood lands will be permanently replaced sooner than typical cypress lands in the reclamation of swamps.

(6) Natural reproduction, following the earlier cuttings by the selection system, is generally good, and this method promises well wherever sufficient seed trees have been left. Clear cutting in virgin stands results in poor restocking.

These several qualifications indicate both the demands to be met and the relative position to be occupied by cypress in the future forests of the South.

LOW VALUE OF LAND AND GROWING STOCK.

It has been shown (p. 52) that uncleared and undrained lands covered with stumps and a mass of surface roots are of low and generally uncertain value, and that the cost of draining and clearing is somewhat more than the present value of similar cleared and drained lands. The actual present value of the timber left on the land after conservative cutting is very small compared with its potential value.

The figures given in Table 15 apply to the cypress in a typical mixed cypress and hardwood stand, cutting an average of approximately 12,500 board feet of cypress per acre. This is a safe average for medium mixed cypress, since pure cypress often cuts from 15 to 25 thousand board feet over large areas. It should be noted that the volume of the trees 16 inches and over in diameter constitutes 94 per cent of the stand. By cutting to a diameter limit of 18 inches, the amount of merchantable timber left standing on the average will likely amount to between 8 and 10 per cent of this particular stand. In other stands not so well stocked with younger classes it will be less.

TABLE 15.—*Cypress trees by diameter classes and corresponding volumes in a representative stand.*¹

Diameter (breast-high).	Trees per acre.	Volume per acre (Doyle rule).		Per cent of total stand.
		Average tree.	Total stand.	
<i>Inches.</i>		<i>Board feet.</i>	<i>Board feet.</i>	
1 to 5.....	16.0			
6 to 10.....	11.0	4	44	0.3
11 to 15.....	9.8	72	706	5.7
16 to 20.....	8.2	200	1,640	13.1
21 to 25.....	5.4	413	2,230	17.9
26 to 30.....	3.9	760	2,964	23.8
31 to 35.....	2.0	1,121	2,242	18.0
36 to 40.....	1.4	1,476	2,066	16.6
41 to 45.....	.2	1,821	364	2.9
46 to 50.....	.1	2,160	216	1.7
Total.....	58.0		12,472	100.0

¹ Cypress in mixture with hardwoods (about one-third of the latter); 21 trees per acre of cypress 16 inches and over in diameter. Representative of large tracts in Florida and Louisiana.

In the above representative stand with a good stocking of young trees, 5.7 per cent of the volume is contained in the trees from 11 to 15 inches in diameter. A diameter limit of 16 inches in this stand would mean leaving approximately 750 board feet, or a value of \$3.75, at an average stumpage rate of \$5 per thousand feet. The combined value of land and timber left in cutting to a 16-inch diameter limit will probably average generally between \$4 and \$7 per acre.

Lumbermen in very many cases fail to consider fairly the very low relative stumpage value of timber in the small sizes. Small trees obviously are utilized at relatively little profit, or often at a loss,

because of the high expense in handling and the low grade of the product. The percentage of increase in volume is relatively much greater in trees from 10 to 18 inches in diameter than in larger trees.

COST OF PROTECTION, THINNING, ETC.

The holding of a small portion of the virgin stand for a second cut entails no essential additional outlay. Fire menace is at a minimum, and no other form of damage requires attention, including timber trespass and grazing. In case planting is done to fill in blank spaces, an additional expense of between \$4 and \$10 per acre must be reckoned. A detailed account is given on pages 67 to 69.

VALUE OF CROP PRODUCED.

Cypress trees from 15 to 18 inches in diameter left on cut-over land in southern Louisiana,¹ measured in 1908, 1910, and 1913, were found to be increasing in breast-high diameter at the rate of an inch in a little over two years. Trees of the younger classes on cut-over lands will be stimulated in growth by the admission of additional light. Table 16 shows the average volume in board feet for cypresses of various diameters, also the corresponding increase in volume for each increase of 1 inch in breast-high diameter. For example, a 15-inch cypress contains 23 board feet more than a 14-inch tree. If the rate of growth is an inch in diameter in 3 years, the volume of the tree is increasing 8 board feet a year. Growing at the same rate, an 18-inch tree adds about 10 board feet, and a 24-inch tree 20 feet annually. A slower growth of 1 inch in 4 years will give slightly decreased figures. It is known that the rate of diameter growth remains about constant in cypress for the sizes shown in the table.

TABLE 16.—Rate of increase in volume for second-growth cypress trees, 10 to 24 inches in diameter (Southern United States).

Diameter breast- high.	Volume of tree (Doyle rule).	Increase in volume from preceding di- ameter class.		Annual rate of increase in volume.		
				Rapid growth (1 inch in- crease in 3 years).	Moderate growth (1 inch in- crease in 4 years).	Slow growth (1 inch in- crease in 6 years).
<i>Inches.</i>	<i>Board feet.</i>	<i>Board feet.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
10	20					
11	37	17	85	28.3	21.2	14.2
12	54	17	46	15.3	11.5	7.7
13	72	18	33	11.0	8.2	5.5
14	92	20	28	9.3	7.0	4.7
15	115	23	25	8.3	6.2	4.2
16	141	26	23	7.7	5.8	3.8
17	169	28	20	6.7	5.0	3.3
18	200	31	18	6.0	4.5	3.0
19	234	34	17	5.7	4.2	2.8
20	271	37	16	5.3	4.0	2.7
21	312	41	15	5.0	3.8	2.5
22	359	47	15	5.0	3.8	2.5
23	413	54	15	5.0	3.8	2.5
24	473	60	15	5.0	3.8	2.5

¹ Belle River, Grand River Basin, St. Martins Parish, La.

The approximate annual money increment of the tree may be readily calculated by multiplying the number of board feet the tree is producing annually by the current stumpage rate. Thus, at \$5 per thousand board feet,¹ the trees in Table 16 are increasing in value annually at the rate of about 4 cents each for a 15-inch tree, 5 cents for an 18-inch tree, and 10 cents for a 24-inch tree. This indicates also the increasing rate of annual money returns from trees of large size. By ascertaining the number of trees of each diameter group and applying to them the figures shown in Table 17, the total increase of the stand may be obtained in round numbers. Average annual increases in value of about \$4 per acre represent approximately the enhancement of a stand of 100 trees per acre of an average present size of 15 inches, growing at the rate of 1 inch in diameter in 3 years; at a slower rate of 1 inch in 4 years the increase will be about \$3 per acre.

In the absence of yield tables, which are difficult to obtain in the uneven or all-aged cypress stands, the above calculation, based upon Table 17 and volume and stand tables, may be used as a satisfactory approximation of the increasing value of young growing cypress.

In the representative stand used for illustration (p. 57), approximately 750 board feet or 6 per cent of the total volume would be left if the original stand were cut to a 16-inch diameter limit; if cut to an 18-inch limit about 10 per cent of the stand would remain.² Growing at the rate of 1 inch in 4 years, the trees left will increase 5 inches in diameter in the next 20 years, reaching the next higher diameter class of 16 to 20 inches. Allowing 10 per cent loss in numbers for death and permanent injury, there will then be about 9 merchantable trees per acre, from 16 to 20 inches in diameter, with a total volume of 1,800 board feet.³ This is an increase of 1,050 feet, or 140 per cent. A stumpage rate of \$5 per thousand feet gives a total value of \$9, or an increase of \$5.25. If the stand is cut to an 18-inch minimum limit, about 1,250 board feet will be left, valued at \$6.25. In 20 years the 12 trees will increase by about 1,810 feet, or approximately 145 per cent, and be worth \$15.30. Stumpage in 20 years may be higher than \$5, but only present values are used in these calculations.

If these figures of money yield do not appear attractive as compared with other forms of investment, the unproductive character of the land except for timber growth must not be overlooked.

¹ Good grade of second-growth cypress.

² Based upon Table 20.

³ Based upon Table 15.

TABLE 17.—Increase in board feet and money value in 10, 20, and 30 years for cypress trees of various diameters, at stumpage price of \$5 per thousand feet.

	Tree diameter (breast high) (inches).											
	12			14			16			18		
	Rate of growth (years required for 1 inch increase in diameter).											
	3	4	6	3	4	6	3	4	6	3	4	6
Present volume of tree (board feet).....	54	54	54	92	92	92	141	141	141	200	200	200
Annual increase in volume.....	5.7	4.2	2.8	6.7	5	3.3	8.7	6.5	4.3	10.3	7.8	5.2
Volume in 10 years.....	111	96	82	159	142	125	228	206	184	303	278	252
Volume in 20 years.....	168	138	110	226	192	158	315	271	227	406	356	304
Volume in 30 years.....	225	180	138	293	242	191	402	336	270	509	434	356
Present value of tree.....	\$0.27	\$0.27	\$0.27	\$0.46	\$0.46	\$0.46	\$0.70	\$0.70	\$0.70	\$1.00	\$1.00	\$1.00
Annual increase in value.....	.028	.021	.014	.034	.025	.016	.044	.032	.022	.052	.039	.026
Value in 10 years.....	.56	.48	.41	.80	.71	.62	1.14	1.03	.92	1.52	1.39	1.26
Value in 20 years.....	.84	.69	.55	1.13	.96	.79	1.58	1.36	1.14	2.03	1.78	1.52
Value in 30 years.....	1.12	.90	.69	1.46	1.21	.96	2.01	1.68	1.35	2.54	2.17	1.78

	Tree diameter (breast high) (inches).								
	20			22			24		
	Rate of growth (years required for 1 inch increase in diameter).								
	3	4	6	3	4	6	3	4	6
Present volume of tree (board feet).....	271	271	271	359	359	359	473	473	473
Annual increase in volume.....	12.3	9.2	6.2	15.7	11.8	7.8	20	15	10
Volume in 10 years.....	394	363	333	516	477	437	673	623	573
Volume in 20 years.....	517	455	395	673	595	515	873	773	673
Volume in 30 years.....	640	547	457	830	713	593	1,073	923	773
Present value of tree.....	\$1.36	\$1.36	\$1.36	\$1.80	\$1.80	\$1.80	\$2.36	\$2.36	\$2.36
Annual increase in value.....	.062	.046	.031	.078	.059	.039	.10	.075	.050
Value in 10 years.....	1.97	1.82	1.66	2.58	2.38	2.18	3.36	3.12	2.86
Value in 20 years.....	2.58	2.28	1.98	3.36	2.98	2.58	4.36	3.86	3.36
Value in 30 years.....	3.20	2.74	2.28	4.15	3.56	2.96	5.36	4.62	3.86

TREATMENT OF VIRGIN STANDS.

From the lumberman's standpoint the first aim in cutting virgin stands should be the complete utilization of the material taken. Close utilization of the tops and butts has been practiced for some years in Louisiana, and there seems no good reason why this would not be equally profitable along the southern Atlantic Coast, where lower transportation rates are offered to the central market region in the northeastern States.

Too often customs from the earlier and more primitive logging days survive tenaciously, in spite of advancement and change in economic conditions which make complete utilization of trees profitable. Considering the high value of cypress stumpage, it is believed to be an actual loss under ordinary conditions to leave high stumps and large sound tops. Felling the trees at the height at which they have been girdled usually results in heavy waste of sound timber.¹

¹ Girdling is done at a high point to avoid unnecessary labor.

The stumpage value of material left in high stumps will often pay for felling and cutting up the tree. Complete utilization brings down the fixed or overhead expense, leaving the operating cost alone to furnish the basis for figuring the profit or loss of taking out the individual material. This distinction, it is feared, is not clearly drawn by the average operator. The installation in the main mill of a small circular saw with 3-man crew to work up logs from small trees, top logs, and others of low grade has been suggested as feasible in mixed sizes and under ordinary conditions.¹ Logs of this class tie up a big saw crew and by reducing the daily output increase correspondingly the cost of manufacture.

The second aim in cutting virgin stands should be the welfare of the succeeding timber crop, to be secured by early and complete restocking of the tract. It will be clearly understood that this applies only to situations which promise to remain either permanently or for a long period as swamp land.

The essential requirements for satisfactory reproduction in virgin stands are sufficient seed trees and openings to light. The vigorous smaller trees, left because they are increasing at their most rapid rate both in size and money value, will produce seed of the highest quality though limited in quantity. The stand might be cut to a minimum diameter of 18 inches at breast height. A tree of this size gives a butt log from 12 to 14 inches in diameter at the top end. In virgin stands such trees vary from 130 to 170 years old and in second-growth or open-grown stands from 65 to 90 years. For the best results in reproduction it is desirable to leave standing on the tract not less than from 4 to 8 trees per acre, from 10 to 18 inches in diameter. The practice of felling overmature trees which clearly contain no merchantable cypress timber is beneficial in clearing up the area of pecky fungus, but undesirable where a deficiency in younger seed trees exists. Old trees quite regularly produce crops of seed, which, although less desirable, may be needed for restocking the ground.

Millions of young cypress trees are cut indiscriminately for such uses as raft binders, car stays, mud sills, and cribbing logs on temporary lines, where the ordinary hardwoods would answer the requirement and should be taken in preference to young cypress. Some conservative operators in Florida are requiring attention on the part of their employees to the protection and encouragement of cypress reproduction and young trees. Groups or clumps of such trees are often unnecessarily injured in felling large trees; in some cases skidder sets and logging spurs may just as well be located in other places. The removal of the hardwoods should be accomplished to as full a degree as possible in order to make openings for the more valuable cypress

¹ To be located in the space beyond the main saw.

and reduce the competition for light. Heavy openings without adequate seed trees contain a rank undergrowth of saw grass, cat-tails, iris, and various shrubs, but the same openings supplied with an abundance of cypress seed will start a new timber crop.

Groups or small stands of polewood cypress occurring in virgin stands should be thinned in order to give the better individuals increased space for crown development, as well as root space if subject to acid water or periods of summer drought.

CUT-OVER CYPRESS AREAS.

It is doubtful if any operations toward the improvement of old cut-over cypress tracts will pay for themselves. Reproduction following the early cuttings has generally been good. On one logged tract in Iberville Parish, La., an average of 340 cypress trees per acre 20 to 30 years old, were counted.¹ Plate V shows saplings filling in small openings in the stand. Since the general introduction of overhead cableway skidders and the resulting very clean logging of cypress, the possibility of a future cypress stand has been practically eliminated from several million acres. The complete removal of a mature virgin cypress stand without making provision for the succeeding crops is giving results similar to those from the clean cutting of virgin stands of white and longleaf pines. The rank growth of shrubs and vines and the sprout reproduction in mixed cypress and hardwood cuttings makes it doubtful whether the expenditure of money for reforestation would bring a profit, especially when the uncertainty about future uses of the lands is considered.

CARE OF YOUNG STANDS.

Thinning is one of the few operations to be considered in dense young second-growth stands. The characteristic cypress "ponds" and shallow swamps over the coastal plain contain pure stands of cypress of comparatively small size, including a good deal of young growth. Much of the suppression of young trees in groups can be overcome by thinning and improvement cutting. In some cases this will be profitable, although in others the materials removed will not repay the expense of thinning. Only in the former case should the operation be attempted. There are two methods of thinning: (1) Removing the smaller trees which are crowded or overtopped by their larger neighbors, and (2) taking out the larger dominant, and "wolf" trees which suppress the growth in several adjacent trees of average size. Because of the all-aged character of cypress stands, the first method will generally give better results, varied occasionally by the removal of one or more dominant trees from a group in order to benefit adjacent trees by affording light and perhaps root space. After thinning, the new growth will be distributed among fewer individual

¹ By McLean, F. T. Manuscript report on cypress, Forest Service, 1908.

trees and will produce a higher average grade of timber. Since cypress seeds frequently and in good quantity, seedlings may be expected to fill in the blank spaces left.

Thinning or selective cutting for ties, poles, etc., or taking the larger trees down to a diameter limit of from 14 to 18 inches, can be practiced as a rule in ponds and small inland swamps, because of their accessibility during fall dry weather, and the ease with which small skidding engines mounted on runners can be moved and set up along their margins. On account of unfavorable conditions, growth is relatively slow in shallow undrained cypress ponds.

PROFITABLENESS OF GROWING CYPRESS POLES.

The profitableness of growing cypress on short rotations, reckoning on the basis of present prices, promises a rather better showing for poles than for ties and possibly also than for saw timber.

In 60 years second-growth cypress trees will yield poles 30 to 32 feet long, 6 inches at the top and about 14 inches at the butt. Such poles are worth in stumpage from 25 to 50 cents apiece. In 100 years 40-foot poles about 8 inches at the top end are obtained, worth at present about \$1 each in the tree. Average well-stocked, pure stands, 50 to 75 years old, contain approximately from 250 to 350 trees per acre. The stumpage value in poles at current prices will amount to \$75 to \$150 per acre at 60 years, or \$200 to \$300 at 100 years. Figuring on a 60-year rotation:

Value of land, \$2.50 ¹ per acre, compounded at 6 per cent annually for 60 years.....	\$82.48
Taxes at 2 cents annually compounded for 60 years at 6 per cent.....	10.66
	93.14

This indicates the profitableness of holding young cypress for poles on lands, with an average value of \$2.50 per acre and assessed at 60 per cent of their real value. At a stumpage production of \$100 an acre for fully stocked natural stands a profit of a little over 6 per cent, compounded annually, will be realized at the end of 60 years. In case artificial stocking is necessary by planting seedlings, costing \$6 an acre, on land valued at \$2.50 per acre, the same crop will produce a net profit on the total investment of about 4 per cent, compounded annually.

From the values given above it is clear that growing cypress poles on a 100-year rotation would be less profitable, even starting with fully stocked natural stands, than on a 60-year rotation. Similar calculations indicate that it would be comparatively unprofitable to grow ties except for the reduced cost of getting them to market. The promise of success in growing cypress is greater on small tracts near local markets and also where water logging is possible.

¹ About 1.7 times the assessed taxation value of \$1.50 per acre.

PLANTING AND SOWING CYPRESS.

The establishment of young stands by sowing or planting will probably always be of limited application in the case of cypress. On a small scale, however, where it is desired to devote wet or moderately moist lands to their highest form of timber production, the planting of cypress in the Eastern and Southern States will unquestionably be practicable. Experiments and nursery practice seem fully to establish the adaptability of cypress and the success of the method.

CYPRESS UNDER CULTIVATION.

In many parks, lawns, and arboretums of both Europe and the United States cypress has proved to be a hardy and rapid growing tree. When grown in the open, its habit resembles that of eastern red cedar, but it is somewhat more cylindrical. On account of its light, feathery foliage and narrow pyramidal shape cypress is a tree of distinctive appearance and striking beauty. (See Pl. XII.)

Commercially, cypress is being increasingly planted on account of its good rate of growth and the value of its wood. In the last few years 75,000 seedlings have been planted in Ohio under the general direction of State forestry organizations. The older cypress plantations in Ohio are reported by the State forester¹ as having made a satisfactory record in the production of timber. The potential range for planting appears to reach as far north as the southern portions of New England, New York, and Michigan. Individual trees will grow somewhat farther north, but when young are susceptible to injury by freezing.

Cypress does not require, as is usually believed, heavy, wet, swamp soils. It does not thrive in hot, dry situations or in pure sand, but does well in ordinary loamy, calcareous, and clay soils, which as a class are retentive of moisture. The requirements of cypress call for the more favorable class of hardwood sites, including moist slope and bottom land, typical soil for such species as beech, maples, basswood, tulip poplar, catalpa, elm, oak, sycamore, and cottonwood. Trees in the District of Columbia are growing well near the Potomac Flats (Pl. XII) and also on Meridian Hill, about 200 feet in local elevation above the river. Because of previous good results the city of Cincinnati in 1914 planted 40,000 cypress seedlings in forest stands on relatively high, well-drained ground.

GROWTH OF PLANTED CYPRESS.

The rate of growth of individual planted cypress trees is closely comparable to that of the more rapid hardwoods. Under cultivation trees grow from 18 to 24 feet in height in the first 10 years. The best

¹ Edmund Secrest, State Forest, Wooster, Ohio.



PROGRESSIVE STAGES IN THE DEVELOPMENT OF CYPRESS SEEDLINGS.

Seed at beginning of series and cone or "ball" in upper left-hand corner. (Seven-ninths natural size.)



CYPRESS ON GROUNDS OF U. S. DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

The center tree measures 74 feet in height by 21 inches in diameter (breasthigh), and the group was planted about 1868, so the trees are about 50 years old.

height growth in Ohio, for example, has been 3 feet annually for a few years. In fresh or moist soil west of Columbus, some cypress trees are growing 30 inches a year in height. In dry situations, such as eroded clay hillsides and in loose gravelly soils, growth is less than a foot a year. In the District of Columbia cypresses 50 years old are from 20 to 30 inches in diameter by 65 to 84 feet in height, excelling all associated species in rate of height growth. Measurements on growth in forest plantations are not available, but observations show a good development of cypress in height and diameter when properly spaced in planted stands.

NURSERY PRACTICE.

Cypress may be grown from seed in nursery beds as successfully as many of the common conifers.

The structure of the seed and germination tests described on pages 29 to 30 indicate certain requirements of moisture and heat that should be carefully followed for the successful and economical germination of cypress seeds. Among these are (1) the softening of the seed coats, making it advantageous to soak cypress seeds in water (apparently from four to six weeks¹) prior to sowing in the seed bed; (2) the requirement of a rather high degree of heat for germination, making it advisable to sow seeds in late spring or early summer, when a good degree of heat is present. Undoubtedly the highest germination can be secured by sowing in a protected hotbed or greenhouse, although this method is not necessary. The soil should be kept well supplied with moisture. Mulching will be an effective aid.

Some nurserymen store the seed where they will be cool and moist over winter. Stratification will accomplish this, and moderate freezing is said not to injure the seed. The requirements for germination are warmth and continuous moisture, both in greater abundance, however, than is required by some of the upland pines. Light mulching of seed beds is often very helpful. Prof. J. W. Toumey, of the Yale Forest School, states that cypress seed sown outdoors at New Haven, Conn., in the spring germinates freely in about six weeks, with about 40 per cent germination. Cypress resembles the hardwoods in requiring a deep loamy soil. Sowing the seed in drills in seed beds permits of light cultivation of the soil, while broadcasting better utilizes seed bed space.

Clean seed averages about 5,000 to the pound. Commercial seed is not cleaned but contains from 25 to 40 per cent by weight of cone scales² (fig. 6) and sells usually at 75 cents to \$1 a pound. The

¹ Comparative tests have not been made on duration, character of water, whether stagnant or fresh, etc., in this preliminary treatment of cypress seed.

² See p. 29 for further description of seed. Since the cone scales are only slightly larger than the seed, separation is not attempted, which accounts for the trash contained in commercial seed.

actual cost of collecting seed from the trees where logging is in operation is considerably less. The month of October is the most favorable time for collecting seed, which should be done before the cones ("balls") are sufficiently ripe to open or fall off when the tree is felled. Where no logging is in progress seed may be gathered by climbing moderate-sized trees where cones can be reached by hand. Lineman's climbers are useful in this operation. Various devices may be used for collecting the cones beyond arm's length. After being picked the cones should be spread on trays, screen, canvas, or tight floors to dry.

Young seedlings show exceptional vigor and are transplanted with the greatest ease, provided soil moisture is plentiful. The root system is comparatively shallow. In the dryer natural situations the tap-

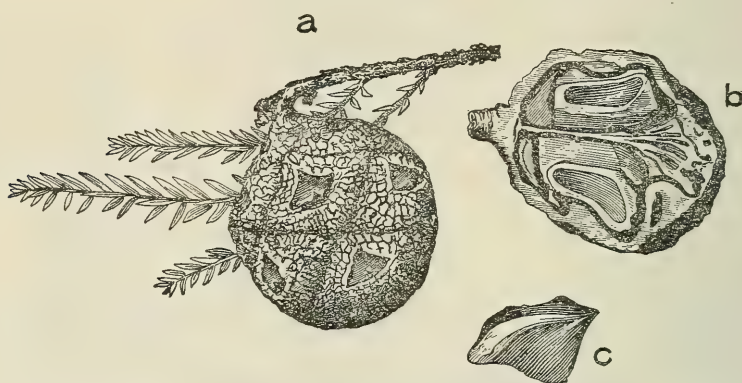


FIG. 6.—Cypress cone and seed; *a*, Fruiting branchlet; *b*, section of cone showing two of the seed; *c*, seed (about natural size).

root even in young saplings has been found to extend downward for several feet. In the dryer nursery soils it is essential to supply abundant moisture, and mulching will prove very helpful. Additional growing space may be required if the seedlings are kept in the nursery during the second season. If the seedlings are transplanted in the nursery, a spacing of 2 to 4 inches in rows 4 to 8 inches apart will probably be about right in most soils during the second season.

The hardiness of cypress seedlings in the Northern States depends somewhat on where the seed was grown. Louisiana and Florida seed, for example, have been found to produce seedlings less able to stand the cold winters than seed from the more northern portion of the range.¹ The amount of seed from more northern regions is limited, however, by the failure of cypress to mature seed to any considerable extent over the extreme northern portion. At New Haven, Conn., it has been found impossible to collect fertile seeds from trees growing in the locality, while perfectly hardy cypresses have been grown from

¹Toumey, J. W., Yale Forest School, New Haven, Conn.

seed collected farther south. Experiments seem to show that seed from the slow-growing "pond" form of cypress will produce inferior stock to that grown from seed from thrifty trees favorably situated. Because the poorer seed is much more accessible, it is apt to find its way freely to the market. No point of difference is known by which to distinguish seed from the two or more botanical forms.

PLANTING.

Practically all experience points to the general hardiness and adaptability of cypress for planting in forest stands. The best time for planting appears to be during late fall or early winter, so that the seedlings can become established during the subsequent period of low water. Planting in the spring should be done just before the buds begin to swell. Although leafless in winter, like the hardwoods, cypress requires care in handling in keeping the roots always moist and the fine rootlets as intact as possible; in this respect, cypress appears intermediate between the hardwoods and ordinary conifers.

Seedlings are best transplanted at the end of the first or second year; the older and larger stock will be found preferable for tracts inundated for periods of considerable duration. One-year stock will likely be found satisfactory in ordinary situations. Cypress seedlings are semiaquatic and will grow standing in shallow water.

Since the foliage is browsed, protection against grazing animals when closely confined is necessary in order to avoid injury to plantations.

Because of the small amount of cypress that has been planted, evidence based upon measurements can not be furnished to show the financial results to be expected. Hence it is impossible at this time to offer any definite recommendations in regard to the advisability of planting cypress on a commercial scale.¹ Material of the sort needed to form a basis for such recommendations will become available with the further development of young planted stands, and additional experience in methods of planting.

The central Mississippi, Ohio Valley, and middle Atlantic coast regions offer promise of being well adapted to commercial planting. As with all species of trees, the profitableness depends essentially upon various local conditions after all questions of growth and general adaptability of the species from a silvicultural standpoint have been settled. Planted cottonwood, for example, has proved to be profitable on some of the heavy, less valuable bottoms of the central Mississippi Valley.² Unless treated, however, its wood is very short lived in contact with the soil, while the heartwood of cypress is very durable, and therefore well fitted in this respect for such uses as posts,

¹ Ohio is taking the lead above all others in planting cypress. Address the State Forester, Wooster, Ohio.

² Bull. 24, U. S. Dept. of Agr., "Cottonwood in the Mississippi Valley."

poles, and ties. In the Southern States the problem of utilizing the cut-over swamp land to the greatest advantage involves the question of planting cypress.

The cost per thousand of growing cypress in lots of 100,000 seedlings is estimated as follows:

One-year seedlings.....	\$3.00 to \$4.00
Two-year seedlings.....	3.75 to 5.00
Two-year stock (one-year transplanted).....	5.00 to 6.50

The expense of planting the seedlings in their permanent situation will vary with the distance from the nursery, the character of the soil, whether soft or moderately firm, and the spacing used. The

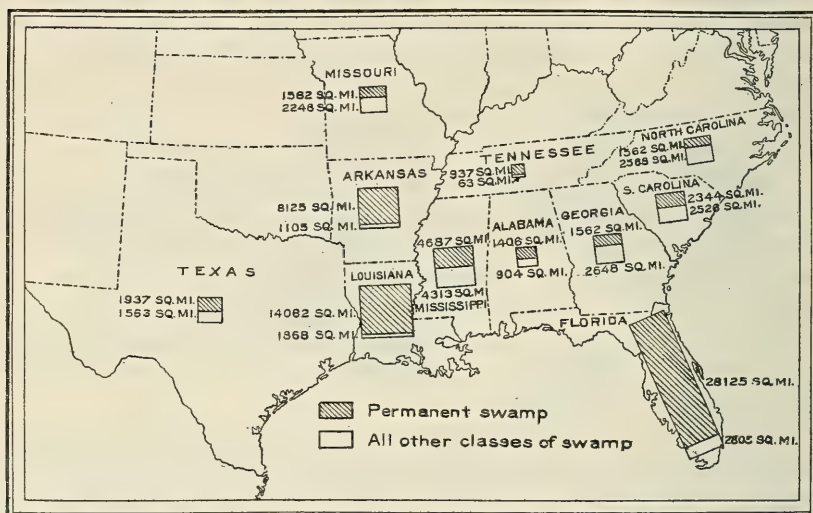


FIG. 7.—Areas of permanent swamp in the United States.

cost of planting per thousand, including transportation, should be about as follows:¹

One-year seedlings.....	\$2.75 to \$4.00
Two-year seedlings.....	3.25 to 5.00
Two-year stock (one year transplanted).....	4.50 to 6.50

Unless the land is entirely cleared, which seldom occurs, it is not desirable to plant an entire acre with a regular spacing. In planting open places it may be advisable to use a close spacing, but on the whole a tree every 8 feet in either direction should be sufficient.

¹ This estimate is based on the production of 100,000 seedlings a year. Increasing the size of the operation noticeably decreases the cost per thousand. While growing a smaller number usually increases the cost, the farmer is often in a position to collect seed and raise five to fifteen thousand cypress seedlings in garden soil at very little expense.

Under average conditions the total cost per acre of growing and planting nursery-grown cypress stock of different ages and with different spacing will be about as follows:

Kind of stock.	Spacing.		
	10 by 10 feet (436 per acre).	8 by 8 feet (680 per acre).	6 by 6 feet (1,210 per acre).
One-year seedlings.....	\$3. 10 to \$3. 60	\$4. 50 to \$5. 00	\$7. 40 to \$8. 60
Two-year seedlings.....	3. 80 to 4. 50	5. 40 to 6. 30	9. 30 to 10. 80
Two-year stock (one-year transplanted).....	4. 70 to 5. 80	7. 00 to 8. 00	12. 00 to 16. 00

The situations where the most intensive classification and development of southern swamp lands is likely to make forest planting of cypress feasible are (1) large tracts of permanent swamp covered with stumps, under the ownership of a strong permanent organization, either private or public; and (2) small areas, near good markets with transportation facilities, which it is desired to manage intensively in connection with other business such as farming.

APPENDIX.

TABLES.

VOLUME.

Tables 18 to 21, inclusive, show the volume in board feet for cypress of different diameters measured at breastheight (4.5) and at 20 feet from the ground, or about the top end of the first 16-foot log.¹

TABLE 18.—*Volume in board feet of cypress by Doyle log rule, based upon diameter at 20² feet and number of logs in tree (Maryland and South Carolina).*

Diameter of tree at 20-foot above ground ³ .	Number of 16-foot logs.						Height of stump.	Average length of log.	Diameter (inside bark) of top.	Basis.
	1	2	3	4	5	6				
	Volume—board feet.									
<i>Inches.</i>							<i>Feet.</i>	<i>Feet.</i>	<i>Inches.</i>	<i>Trees.</i>
8	15	25	35	45	-----	-----	2.3	13	6	14
9	25	35	50	65	-----	-----	2.4	14	6	12
10	35	50	65	85	100	-----	2.5	14	7	20
11	55	75	90	115	140	-----	2.6	15	7	21
12	75	100	125	150	175	-----	2.7	15	8	19
13	100	125	160	190	220	250	2.8	15	9	18
14	125	160	195	240	280	330	2.9	15	9	15
15	145	195	240	290	340	390	3.0	16	10	21
16	-----	230	290	340	400	470	3.1	16	10	37
17	-----	280	340	400	470	540	3.1	17	11	28
18	-----	330	400	480	550	630	3.2	17	12	34
19	-----	390	470	560	640	730	3.3	17	13	22
20	-----	460	550	640	740	850	3.4	17	14	19
21	-----	520	630	740	850	970	3.5	18	15	22
22	-----	590	710	840	970	1,110	3.5	18	16	30
23	-----	660	800	950	1,110	1,280	3.6	18	17	20
24	-----	730	890	1,070	1,260	1,460	3.7	18	18	23
25	-----	800	990	1,200	1,410	1,630	3.7	18	19	14
26	-----	870	1,090	1,330	1,570	1,830	3.8	18	20	19
27	-----	950	1,200	1,460	1,730	2,000	3.8	19	21	12
28	-----	-----	1,300	1,600	1,900	2,200	3.9	19	23	5
29	-----	-----	1,410	1,730	2,060	2,400	3.9	19	24	7
30	-----	-----	1,520	1,870	2,230	2,600	4.0	19	25	5
437										

¹ Since the form of tree growth is apt to vary somewhat under widely different climates and soils, volume tables are usually considered more or less local in their application. In the case of cypress, however, since wide differences in growth appear to be present within any specific locality, volume tables for cypress for one region are generally applicable and may be used for other portions of its commercial range.

² Top of first 16-foot log in larger trees.

³ Measured outside bark.

TABLE 19.—*Volume in board feet of cypress by Scribner log rule, based upon diameter (at top of first 16-foot log) and number of 16-foot logs in tree (Maryland and South Carolina).*

Diam- eter ¹ at 20 feet.	1 log.		2 logs.		3 logs.		4 logs.		5 logs.		Basis.
	Vol- ume.	Diam- eter inside bark of top.	Vol- ume.	Diam- eter inside bark of top.	Vol- ume.	Diam- eter inside bark of top.	Vol- ume.	Diam- eter inside bark of top.	Vol- ume.	Diam- eter inside bark of top.	
<i>Inches.</i>	<i>Bd.ft.</i>	<i>Inches.</i>	<i>Bd.ft.</i>	<i>Inches.</i>	<i>Bd.ft.</i>	<i>Inches.</i>	<i>Bd.ft.</i>	<i>Inches.</i>	<i>Bd.ft.</i>	<i>Inches.</i>	<i>Trees.</i>
6	20	6.0									6
7	25	6.8									3
8	30	7.7									7
9	40	8.7	55	6.2							12
10			70	7.0	100	6.1					20
11			85	8.0	120	6.8					20
12			105	8.9	145	7.6					19
13			125	10.0	175	8.6					18
14			155	10.8	205	9.4	260	7.5			15
15			185	11.8	250	10.2	305	8.4	335	6.3	37
16			225	12.8	295	11.1	360	9.1	395	6.9	21
17			265	13.7	350	11.9	425	9.9	465	7.6	37
18			315	14.8	410	12.8	495	10.6	510	8.3	28
19			365	15.9	475	13.9	570	11.5	625	9.1	34
20			415	16.9	540	14.9	645	12.4	715	9.9	22
21			470	17.9	610	15.9	730	13.3	820	10.7	20
22			525	18.9	690	16.9	825	14.2	935	11.5	21
23			580	19.8	775	17.8	935	15.2	1,065	12.4	30
24			640	20.8	865	18.8	1,050	16.2	1,205	13.2	20
25			700	21.8	955	19.7	1,165	17.1	1,350	14.1	23
26			760	22.8	1,045	20.8	1,285	18.1	1,500	14.9	16
27			825	23.7	1,145	21.8	1,415	19.0	1,650	15.8	19
28					1,250	22.6	1,545	19.9	1,810	16.6	12
29							1,675	20.9	1,970	17.5	5
30							1,815	21.7	2,130	18.5	8
							1,955	22.6	2,290	19.3	5
											441

¹ Measured outside bark.TABLE 20.—*Volume in board feet of cypress based upon breast-high diameters, by Doyle and the two-thirds log rule (South Carolina).*

Diameter breast high.	Doyle rule.	"Two- thirds" rule.	Total height.	Used length.	Length of log. ¹	Stump height.	Diameter (inside bark) of top.	Basis.
<i>Inches.</i>	<i>Bd.ft.</i>	<i>Bd.ft.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Inches.</i>	<i>Trees.</i>
10	20	64	65	40		2.7	5.6	
11	37	84	69	41		2.7	6.2	
12	54	105	73	42	20	2.8	6.8	3
13	72	127	76	44	19	2.8	7.4	4
14	92	150	79	45	19	2.9	8.0	2
15	115	174	81	46	18	2.9	8.5	6
16	141	200	83	47	19	3.0	9.1	9
17	169	228	85	48	19	3.0	9.7	2
18	200	258	86	49	19	3.1	10.3	5
19	234	289	87	49	19	3.2	10.8	10
20	271	322	88	50	19	3.2	11.4	11
21	312	361	89	51	18	3.3	12.0	9
22	359	403	90	52	18	3.3	12.6	7
23	413	450	91	53	18	3.3	13.2	7
24	473	500	92	54	18	3.4	13.7	14
25	541	555	93	54	17	3.4	14.3	13
26	613	610	94	55	19	3.5	14.9	13
27	696	667	95	55	18	3.5	15.5	9
28	780	720	95	56	18	3.6	16.1	10
29	832	775	96	56	19	3.6	16.7	14
30	916	830	97	57	18	3.6	17.2	15
31	979	881	98	57	18	3.7	17.8	12
32	1,050	935	98	58	18	3.7	18.3	4
33	1,121	990	99	58	18	3.8	18.8	6
34	1,193	1,040	100	59	19	3.8	19.2	14
35	1,262	1,094	101	59	18	3.8	19.6	10
36	1,333	1,150	101	60	19	3.8	20.0	9
37	1,405	1,203	102	60	18	3.9	20.4	12
38	1,478	1,259	103	60	18	3.9	20.8	7
39	1,546	1,312	104	61	19	3.9	21.1	3
40	1,615	1,369	104	61	18	3.9	21.4	9

¹ Uncurved.

TABLE 20.—*Volume in board feet of cypress based upon breast-high diameters, by Doyle and the two-thirds log rule (South Carolina)*—Continued.

Diameter breast high.	Doyle rule.	"Two-thirds" rule.	Total height.	Used length.	Length of log.	Stump height.	Diameter (inside bark) of top.	Basis
<i>Inches.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Inches.</i>	<i>Trees.</i>
41	1,683	1,424	105	61	19	4.0	21.7	2
42	1,752	1,480	106	62	18	4.0	22.0	2
43	1,821	1,538	107	62	18	4.0	22.3	5
44	1,890	1,591	108	62	19	4.0	22.6	5
45	1,959	1,649	108	63	18	4.1	22.9	2
46	2,025	1,701	109	63	16	4.1	23.1	1
47	2,092	1,759	110	63	18	4.1	23.4	1
48	2,160	1,815	111	63	18	4.1	23.6	3
49	2,230	1,872	111	64	18	4.1	23.9	1
50	2,300	1,930	112	64	18	4.1	24.1	1
								265

TABLE 21.—*Volume of merchantable cypress in board feet by the Scribner and Doyle rules for cypress in Louisiana.*¹

Diameter outside bark at 20 feet.	Diameter breast-high.	Volume.		Total height.	Merchantable length.	Length of log. ²	Stump height. ²	Diameter inside bark of top.	Basis trees.
		Scribner.	Doyle.						
<i>Inches.</i>	<i>Inches.</i>	<i>Board feet.</i>	<i>Board feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Inches.</i>	
8	12.8		20	65	33			5.5	
9	14.2	50	40	70	36	33	3.8	6.2	2
10	15.6	95	60	75	40			6.9	
11	17.0	140	80	79	43	56	3.7	7.6	1
12	18.4	190	110	84	47	28	3.9	8.3	6
13	19.8	240	140	88	50	24	3.5	9.1	4
14	21.1	290	180	91	54	31	3.7	9.8	5
15	22.4	350	230	95	57	22	3.6	10.5	7
16	23.8	410	280	98	59	23	3.7	11.2	8
17	25.1	490	340	101	62	24	3.7	11.9	5
18	26.3	560	400	103	64	14	3.5	12.6	2
19	27.6	650	480	105	66	33	3.9	13.3	4
20	28.8	740	560	107	67	33	3.2	14.0	1
21	30.0	840	660	109	69	34	3.2	14.6	1
22	31.2	950	770	111	70	20	4.2	15.3	2
23	32.4	1,080	890	113	71	25	3.0	15.9	1
24	33.6	1,210	1,020	114	72	39	3.5	16.6	1
25	34.7	1,350	1,170	116	73			17.3	
26	35.9	1,510	1,330	117	73			17.9	
27	37.1	1,670	1,500	118	74	35	3.5	18.6	1
28	38.2	1,850	1,680	119	75	30	5.0	19.3	2
29	39.4	2,020	1,870	120	75	28	4.0	19.9	1
30	40.5	2,200	2,060	121	76	34	3.5	20.6	1
									55

¹ Based upon measurement of 55 trees and must be considered rather as tentative than final. Tables for South Carolina are generally applicable.

² Uncurved.

Referring to Table 18, for example, one learns that a 3-log tree, with a butt log 18 inches in diameter at the upper end contains 400 board feet of merchantable lumber; also that such trees are cut on an average to a top diameter of 12 inches measured inside the bark. The tables are based upon full scale of sound timber. Another form of measurements (Table 20) gives the volume of trees of a specified breasthigh diameter by the Doyle and two-thirds log rules in South Carolina; also the average total height and length, average length of log, stump height, and diameter to which the trunk is utilized.¹

Although based upon insufficient measurements, Table 21 is included here for reference and comparison. It will be found useful for rough approximation for which

¹ Since these measurements were taken, utilization in logging has advanced considerably, so the figures are likely to be too low in total volume and used length and too high in top diameter and stump height.

it should be considered as sufficiently accurate, but for all practical purposes Tables 20 and 21 are to be preferred since they show the number of logs under each diameter class.

TAPER.

Table 22 shows the form or taper of the base for trees of various diameters measured at 7 feet above the ground in Maryland. The relation of height to diameters measured at breastheight for trees in Maryland and Louisiana is given in Tables 23 and 24. Table 23 is based on too few trees to be reliable, but serves as an indication of the relative form.

TABLE 22.—*Basal taper of cypress in Maryland for trees of various diameters.*¹

Diameter at 7 feet (outside bark).	Diameter inside bark.				Basis.	Diameter at 7 feet (outside bark).	Diameter inside bark.				Basis.
	1 foot above ground.	3 feet above ground.	4.5 feet above ground.	5 feet above ground.			1 foot above ground.	3 feet above ground.	4.5 feet above ground.	5 feet above ground.	
Inches.	Inches.	Inches.	Inches.	Inches.	Trees.	Inches.	Inches.	Inches.	Inches.	Inches.	Trees.
1	2.8	2.0	1.8	1.2	-----	19	38.0	26.1	-----	20.7	9
2	4.4	3.1	2.9	2.2	-----	20	40.1	27.6	-----	21.8	14
3	5.9	4.2	3.9	3.3	-----	21	42.2	29.1	-----	22.9	6
4	7.6	5.3	5.0	4.3	-----	22	44.1	30.5	-----	24.1	6
5	9.4	6.5	6.1	5.3	4	23	46.1	32.0	-----	25.2	3
6	11.4	7.7	7.2	6.4	2	24	48.0	33.5	-----	26.4	4
7	13.5	8.9	8.4	7.5	5	25	49.8	34.9	-----	27.6	4
8	15.5	10.1	9.5	8.5	10	26	51.6	36.4	-----	28.8	2
9	17.6	11.4	10.6	9.6	5	27	53.3	37.8	-----	30.1	1
10	19.6	12.7	11.8	10.7	5	28	55.0	39.3	-----	31.2	2
11	21.6	14.1	13.0	11.8	8	29	56.7	40.7	-----	32.5	2
12	23.6	15.5	14.2	12.9	7	30	58.3	42.1	-----	33.7	-----
13	25.7	17.1	15.5	14.0	7	31	60.0	43.6	-----	34.8	2
14	27.8	18.7	16.7	15.1	8	32	61.6	45.1	-----	36.0	1
15	29.8	20.3	17.9	16.2	6	33	63.3	46.5	-----	-----	-----
16	31.9	21.8	19.1	17.3	8	34	64.9	48.0	-----	-----	1
17	33.9	23.3	-----	18.4	3	35	-----	49.4	-----	-----	-----
18	36.0	24.7	-----	19.5	7	36	-----	50.9	-----	-----	-----
											142

¹ Diameters measured at 7 feet above the ground instead of breasthigh.

For trees of known diameter at breastheight up to 20 inches, the taper at 1, 3, 5, and 7 feet above the ground is shown in Table 23.

TABLE 23.—*Height and clear length of virgin cypress in Louisiana based upon diameter.*

Diameter outside bark at 20 feet.	Diameter breast-high.	Height.			Clear length.	Basis.
		Maximum.	Average.	Minimum.		
Inches.	Inches.	Feet.	Feet.	Feet.	Feet.	Trees.
8	12.6	79	65	51	39	-----
9	14.2	85	70	55	43	2
10	15.6	91	75	58	47	-----
11	17.0	96	79	62	50	1
12	18.4	100	84	65	53	6
13	19.8	105	88	68	56	4
14	21.1	108	91	70	59	4
15	22.4	112	95	73	61	7
16	23.8	115	98	76	63	8
17	25.1	117	101	78	65	5
18	26.3	120	103	81	66	2
19	27.6	122	105	83	68	3
20	28.8	124	107	85	69	-----
21	30.0	125	109	87	71	1
22	31.2	127	111	89	72	2
23	32.4	128	113	90	73	1
24	33.6	129	114	92	75	1
25	34.7	130	116	93	76	-----
26	35.9	131	117	95	77	-----
27	37.1	132	118	96	78	1
28	38.2	133	119	97	80	2
29	39.4	134	120	98	81	1
30	40.5	135	121	100	82	1
						52

TABLE 24.—*Height of virgin cypress in Maryland on basis of diameter.*

Diameter breast- high.	Height.			Basis.	Diameter breast- high.	Height.			Basis.
	Maximum.	Average.	Minimum.			Maximum.	Average.	Minimum.	
<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Trees.</i>	<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Trees.</i>
1	16	12	9	19	18	112	89	74	13
2	27	19	13	53	19	115	92	76	16
3	37	26	18	17	20	116	94	79	10
4	45	32	22	14	21	118	96	81	15
5	53	38	29	12	22	120	98	82	9
6	61	44	31	12	23	121	100	84	9
7	67	49	35	1	24	123	101	86	15
8	73	54	40	5	25	124	102	87	7
9	79	59	44	2	26	125	103	88	5
10	84	63	48	5	27	126	104	90	7
11	89	67	52	9	28	127	105	91	12
12	93	71	55	13	29	127	105	91	3
13	97	74	59	11	30	128	106	92	-----
14	101	78	62	16	31	129	106	93	4
15	104	81	66	13	32	129	106	94	2
16	107	84	69	16					
17	110	87	71	10					355

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PROFESSIONAL PAPER

August 24, 1915.

DISPERSION OF GIPSY-MOTH LARVÆ BY THE
WIND.¹

By C. W. COLLINS,

Entomological Assistant, Gipsy Moth and Brown-tail Moth Investigations.

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INTRODUCTION.

The territory infested by the gipsy moth (*Porthetria dispar* L.) is gradually increasing in area, and since isolated colonies are being found each year in woodlands and orchards remote from lines of gravel, the question as to their origin has become more urgent. Many agencies assist in the transportation of the moth in its various stages, but as previous experiments proved that small caterpillars are borne by the wind, it seemed desirable to ascertain to what extent this occurs and the maximum distance they may be blown under field conditions. Much depends upon this factor in diffusion, when devising methods of preventing the spread of this pest, and as a practical result of previous experiments tanglefoot has been used extensively in colonies located in the outside infested towns. Trees are banded with tanglefoot to prevent the small larvæ from ascending to the tops, and thus the chances that these larvæ will be blown long distances are decreased.

¹ An extended report on one of the important phases of gipsy moth control work, conducted under the direction of the Bureau of Entomology, L. O. Howard, Chief, and in cooperation with the various States affected.

To secure further information, the writer, under the direction of Mr. A. F. Burgess, commenced a series of experiments in the spring of 1913 and continued them throughout the following year.¹

PREVIOUS INVESTIGATIONS ON DISPERSION OF THE GIPSY MOTH.

Many investigations of various sources of spread of this insect were conducted during the early nineties by Forbush and Fernald and published by the Massachusetts State Board of Agriculture in 1896. It was found that frequent teaming in and out of the original infested areas (Medford, Boston, and towns closely surrounding) by vehicles transporting larvæ that dropped from infested shade and roadside trees was largely responsible for the general local spread during those years. It was also suggested that the larvæ were occasionally transported by the wind to distances of perhaps 100 yards, but no further observations were made at that time to substantiate this theory. Numerous ways and means of local spread, such as by birds, animals, and man, are treated in this valuable report.

In the spring of 1910 Mr. A. F. Burgess began a series of experiments on dispersion of the gipsy moth the account of which is published as Bulletin 119 of the Bureau of Entomology. A few small experiments were made in the laboratory by releasing silk-suspended first-stage gipsy-moth larvæ in front of an electric fan, and it was found that they soared to a distance of 20 to 30 feet in the air before falling. This led to more extensive experiments conducted under out-of-door conditions. Screens constructed of poultry wire and covered with tanglefoot were stationed at given distances from sources of infestation and watched for catches of larvæ. On a small screen stationed on the marshes near Lynn, Mass., newly hatched larvæ were caught that had been carried 1,833 feet by a west wind at a velocity of 7 to 19 miles per hour.

Numerous records were compiled to show the relation of temperature, wind velocity, and wind direction to the general trend of spread as it has progressed from the original center, Medford, Mass. It was clearly demonstrated that the prevalent southwest winds following the hatching period of the eggs each year has resulted in the more rapid dispersion of the moth to the northeast than in any other direction. Large woodland areas were scouted in various towns, the data of which were compiled and show the extent to which the wind is responsible for the remote and numerous colonies located. The automobile is also included in this report, as a very important factor in carrying the caterpillars both locally and for long distances.

¹ The writer is indebted to Mr. L. H. Worthley and Dr. J. W. Chapman for cooperation and helpful suggestions; to Messrs. C. E. Hood, F. W. Graham, and Harry Blaisdell for the collection of field data; to Mr. H. A. Preston for the preparation of photographic illustrations, and to others of the laboratory force who contributed in various ways.

FORMER INVESTIGATIONS OF HAIRS ON SMALL LARVÆ.

The bodies of first-stage larvæ (Pl. I, fig. 1) are provided both dorsally and laterally with two types of hairs, or setæ, namely, short, smooth hairs bearing a vesicle about the middle and very long, slender ones which are covered with spinules. Wachtl and Kornauth in 1893 first described the aerostatic setæ found on the first-stage larvæ of *P. dispar* L. and *Lymantria monacha* L. and designated the balloon-shaped swellings occurring on these setæ as aerophores. They suggest that these aerophores assist in the dissemination of the young caterpillars through the air.

Prof. Cholodkovsky in 1894 made some investigations and found that the swellings or vesicles shrank in dead larvæ. His discovery tended to weaken the theory that these swellings contain air and to suggest that they may contain a fluid which will naturally dry up after death. He also found that the swellings remained for months in alcohol as full and rounded as in living larvæ, and if the preparation was allowed to dry on a slide the aerophores quickly shriveled. He therefore concluded that they did not contain air but a fluid which was probably poisonous and served as a protection against insectivorous birds.

Igenitzky, a student of Cholodkovsky, in 1897 further studied the glands that give rise to the hairs and verified the findings of the former investigator, who proposed to call the swellings "toxophores." He further states that the rôle of rendering the larvæ more buoyant may better be ascribed to the long thin hairs which resemble the pappus of some plant seeds.

Prof. K. Escherich in 1912 published a résumé of former investigations into the function of the hairs and cites later work by Wachtl and Kornauth in 1907 in which they cling to their former theory of aerophores. The latter found that the vesicles did not contain liquid, as no reaction was noted by immersion in litmus, rosolic acid, or phenolphthalein, indicating that they contained neither alkali nor acid. They did not shrink in alcohol, glycerin, or acetic acid, or excite any capillary action; hence the investigators concluded that nothing but air could be contained in them. Prof. Escherich lays stress on the air refraction noted in connection with these balloons when immersed in glycerin and viewed under the microscope.

T. C. Shcherbakov in 1914 published observations on the gipsy moth in which he deals at length with the function of the hairs on the first and second stage larvæ, and parts of his paper have been translated by Mr. J. Kotinsky of the Bureau of Entomology. Shcherbakov says that the aerophores are not filled with air or gas and that their connection with the glandular cells would indicate that these vesicles are probably filled with a poisonous secretion. Their exceed-

ingly small size, he contends, makes them physically inadequate to sustain the caterpillar in the air. On the other hand, the very numerous, very long hairs which cover the larva, in addition to the wonderful amount of silk it is capable of spinning, point to the general morpho-physiological structure as the factor enabling it to soar.

He compares this ability of the caterpillar with the meaning of soaring as this term is used by V. N. Chitrovo in an epoch-making botanical work on the study of weeds.¹ Soaring is the capability of a body passively to participate in an air current, as if constituting part of it, arising from special characters in the structure of the body. The analogy in function between the wind-borne seed and caterpillar is complete.

Soaring is determined by the coefficient calculated by the following formula:

$$C = \frac{f(\text{cm}^2)}{w(\text{gr})}$$

where C is the soaring coefficient; *f*, the surface area (in square cm.); and *w*, the weight (in grams) of the caterpillar. The coefficient of a bare, freshly hatched first-stage caterpillar is 514.285 and Shcherbakov says that it would be more than six times as great if the area of the hairs were included.

Compared with the Chitrovo soaring table of seeds, the coefficient for the first and second stages of the caterpillar places them among the greatest seed soarers. In a slight wind these caterpillars are capable of soaring. The distance they can cover depends on the topography of the country, the character and abundance of vegetation, the mobility of the caterpillar which in turn depends upon the temperature of the atmosphere, and the availability of foods. The soaring coefficient diminishes sharply for caterpillars in the second stage.

This investigator also states that G. G. Jacobson once, while traveling, observed caterpillars flying in masses toward him, despite the fact that he was at least 17 miles away from the nearest forest.

STUDIES OF STRUCTURE AND FUNCTION OF ACUMINATE AND VESICULAR HAIRS.

Owing to the differences of opinion existing as to the structure and function of the hairs covering the bodies of first-stage larvæ, the writer and Mr. C. E. Hood, with the assistance of Dr. J. W. Chapman, made some tests during the winter of 1914-15. The aim of these experiments was to study both the long acuminate hairs and the short ones bearing vesicles. As the results differ somewhat from those of

¹ Atlas von Samen und Früchten der Feldunkräuter aus Mittelrussland. Bul. für angewandte Botanik, wissenschaftliches Organ des Bureau für angewandte Botanik (Monatsschrift), Jahrg. 7, no. 3, 118 p., 16 fig., 13 pl., March, St. Petersburg, 1914.

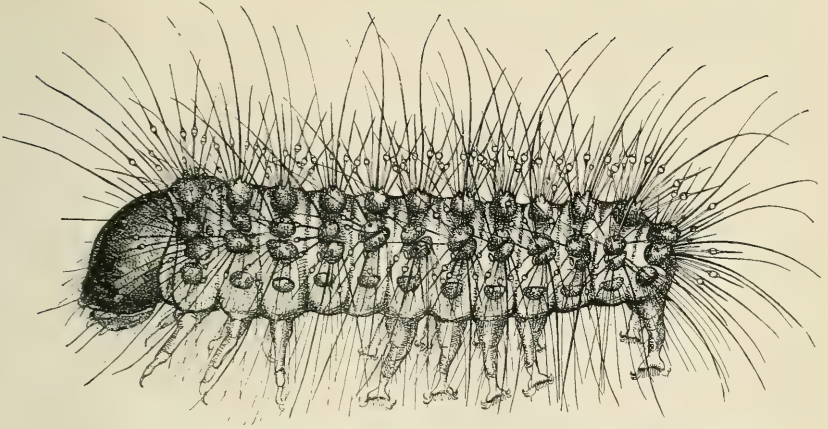


FIG. 1.—FIRST-STAGE LARVA SHOWING TWO KINDS OF HAIRS. (FROM BURGESS.)

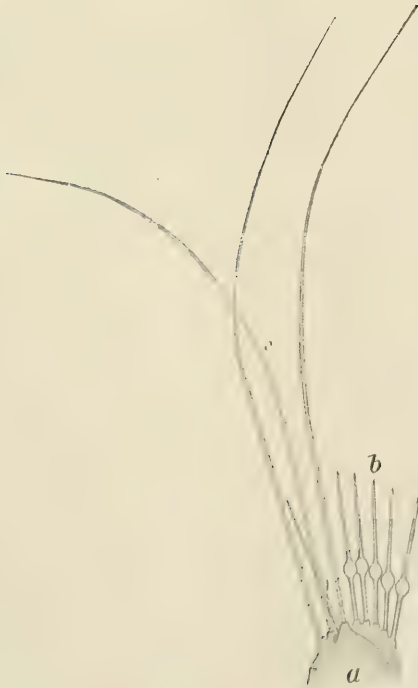


FIG. 2.—*a*, TUBERCLE FROM FIRST-STAGE LARVA SHOWING HAIRS; *b*, VESICULAR HAIRS; *c*, ACUMINATE HAIRS. ALL MUCH ENLARGED. (ORIGINAL.)

GIPSY-MOTH CATERPILLAR SHOWING VESICULAR AND ACUMINATE HAIRS.

previous investigators in that the swellings on the short hairs were found to contain a liquid not yet proven to have toxic properties, it seems advisable that they should hereafter be called vesicular hairs. (Pl. I, fig. 2, *b*.) The term "aerophore" previously applied to the swellings on the short hairs is misleading, as is also the term "toxophore" suggested by Cholodkovsky. The term "acuminate" still applies to the very long slender hairs. (Pl. I, fig. 2, *c*.)

After first-stage larvæ die the swellings on the hairs usually collapse and both air and liquid are present in each type of hair and can be seen under a high-power microscope. A living caterpillar examined in glycerin shows air bubbles occasionally in the hairs and swellings which sometimes extend above and below the latter. The air globules and liquid columns alternate in hairs of dead larvæ, and the difference between the air or colorless liquid present is evident from the typical air refractions in the globular form that air always takes in a liquid; also from the capillary attraction of the liquid contained. Living caterpillars mounted in balsam and examined under a microscope show air bubbles in some of the hairs, but such hairs are exceptions rather than the rule. Caterpillars that have been dead several days show the opposite phenomenon—both air and liquid are seen in them, but air predominates. Some larvæ that had been dead for two years were examined and these contained small short columns of liquid, but air filled the greater portion of the hollow spaces of the hairs. Practically the same was noted in the hairs of an exuvium from a first-stage larva which had also been kept about two years. The vesicles on the hairs had buckled or collapsed and contained air, which was later practically all driven out by heating.

Embryos were dissected from the chorion under balsam and glycerin and then examined in these media. No air globules or what could be termed air refractions were noted in either acuminate or vesicular hairs. Many of the vesicles are only partially distended in this stage. Embryos dissected from the chorion in air contained air globules and columns of liquid alternating in a portion of both types of hairs—probably those ruptured during the dissection.

After some experience it is easy with the aid of a high-power microscope to recognize the difference in refractions through the walls of hairs full of colorless liquid or containing globules of air and columns of liquid alternating. The typical liquid refractions are always seen in uninjured vesicular and acuminate hairs. Only rarely are there air refractions noted in either type on living larvæ. A decided change in aspect is noted in dead larvæ after the vesicle begins to collapse, at which time air finds its way into the hairs.

A number of living larvæ were placed under a bell jar which contained a small amount of concentrated sulphuric acid. After six hours many of the larvæ were dead and upon examination a large

portion of the vesicles of the hairs had buckled or partly collapsed. Larvæ still living at this time presented the same appearance to a slight extent. As a check on this experiment, larvæ were killed with chloroform and after 24 hours showed a smaller proportion of buckled or collapsed vesicles, indicating that sulphuric acid took up moisture from the porous hairs.

Sections were made of the larvæ and cells at the base of the hairs studied, but there could be found no indication of the presence of glandular cells. A large trichogen, however, is present at the base of each hair. This would signify that the liquid inclosed in the hairs is not a toxin, as Cholodkovsky suggests, but a mere colorless mobile liquid secreted during the formation of the hairs. The phenolphthalein and litmus-solution tests were also tried, with negative results, further indicating a neutral liquid. The peculiar shape of the vesicular hairs, however, suggests that they may at one time have had a poisonous function but that it has been lost in the present generations.

The results of the experiments and observations indicate that both the normal vesicular and acuminate hairs are filled with a colorless liquid; that the hairs are hollow throughout, and that the vesicles contain the same media as the remaining portion of that type. A few globules of air were seen in hairs of living larvæ which were noted as exceptions. Air partially replaces the liquid after death, following which period the vesicles collapse. It is therefore probable, as Igenitzky and Shcherbakov have indicated, that the acuminate hairs play the greater rôle in making the larvæ more buoyant, as these are from four to six times as long as the vesicular hairs.

SCOPE OF INVESTIGATIONS ON WIND DISPERSION.

In that the main purpose of the following investigations was to secure data on the maximum distance and the extent to which small larvæ are borne by the wind, it was necessary to find conditions where an abundance of larvæ were present in close proximity to treeless areas. These conditions were best afforded along the beaches in Massachusetts and New Hampshire, where there are stretches of marshland from 1 to $2\frac{1}{2}$ miles wide and many miles long. These marshlands are occasionally flooded with salt water and do not contain vegetation favorable to the development of gipsy-moth larvæ. The areas selected for the experiments were to the east of the heavy infestations, thereby getting all the advantages previously known to accrue from the northwest, west, and southwest winds. The Isles of Shoals, off the coast of New Hampshire, afforded ideal conditions in so far as their remoteness from the mainland was concerned and the fact that the country opposite has been infested since 1905. Locations were also selected in the hills of New Hampshire near the

quarantine line for experiments intended to explain the sources of many infestations found under such conditions.

Screens of poultry wire, to which tanglefoot was applied, were erected in three of the selected locations along the coast and on the Isles of Shoals (Pl. II). Those used in the New Hampshire hill experiments were of a somewhat different type and are described under that head. The screens used along the coast (Pl. III, fig. 1) were of $\frac{3}{4}$ -inch mesh poultry wire stapled to 2 by 4 posts which were set in the ground and held in place at the top by guy wires and wooden braces. The posts were 12 feet high and two sections of wire each 75 feet long and 3 feet wide were fastened to these so that the top selvage was 12 and the lower 6 feet from the ground. The screens contained 450 square feet of wire and were built in three 25-foot sections, the middle section facing the west and the other two angling from the ends about 45° to the eastward. This gave the greatest exposure at all times to the northwest, west, and southwest winds. A runway was attached to the posts at the bottom selvage of the wire to facilitate examinations.

HATCHING OF EGGS IN RELATION TO WIND DISPERSION OF FIRST-STAGE LARVÆ.

Close observations on the time of hatching of egg clusters in the field have been kept since 1912 by laboratory men stationed in different sections of Massachusetts and New Hampshire. The data consulted were collected by Messrs. E. A. Proctor in northeastern Massachusetts, J. V. Schaffner, jr., in Massachusetts south and southwest of Boston, and I. L. Bailey in south-central New Hampshire.

TABLE I.—*First, maximum, and last dates of hatching in 1912, 1913, and 1914.*

Year.	Northeastern Massachusetts hatching.			Southeastern Massachusetts hatching.			South-central New Hampshire hatching.		
	First.	Maximum.	Last.	First.	Maximum.	Last.	First.	Maximum.	Last.
1912.....	May 2	May 11	May 22	May 1	May 15	May 25	May 1	May 14	May 23
1913.....	Apr. 25	May 5	May 27	Apr. 26	May 10	May 21	Apr. 29	May 8	May 14
1914.....	May 11	May 15	May 28	May 9	May 15	May 23	May 11	May 16	May 28

The first larvæ were caught on the screen in northeastern Massachusetts May 9, 1913, and the last June 5, while the largest numbers were removed between May 14 and June 1. During 1914 in the same section the first larva was caught about May 16, while the largest numbers were removed from May 20 to May 27 and the last June 6. One larva was caught in Henniker, N. H., as late as June 13, 1914.

In a year of normal hatching, as in 1913, wind dispersion was noted about two weeks after first hatching and one week after hatch-

ing was completed. In 1914 there was an abnormally late spring, which shortened the hatching season, and wind dispersion was noted about one week after the first date and continued about the same period after the last was observed. The total period over which winds spread may be expected is from 27 to 30 days in a normal spring, and from 18 to 20 days during a late spring. Ordinarily the maximum dispersion is effected during 10 to 15 days of high temperatures and favorable winds.

LONGEVITY OF FIRST-STAGE LARVÆ AFTER BECOMING ENTRAPPED IN TANGLEFOOT.

In connection with the experiments conducted by using tanglefoot on screens to catch caterpillars blown by the wind, it became essential to know about how long they would live after becoming entangled. As a test, tanglefoot was smeared at various depths on heavy paper and 100 caterpillars dropped into these. Examinations were made at intervals from the time the experiment was started, and it was noted that after three hours practically all were living; after six hours only two were attempting to move, and these were in a very thin smear. After eight hours 65 were dead, and 35 showed signs of life when disturbed. The following morning, after 24 hours, all were dead except seven, and these were in very thin smears, which had little effect upon them.

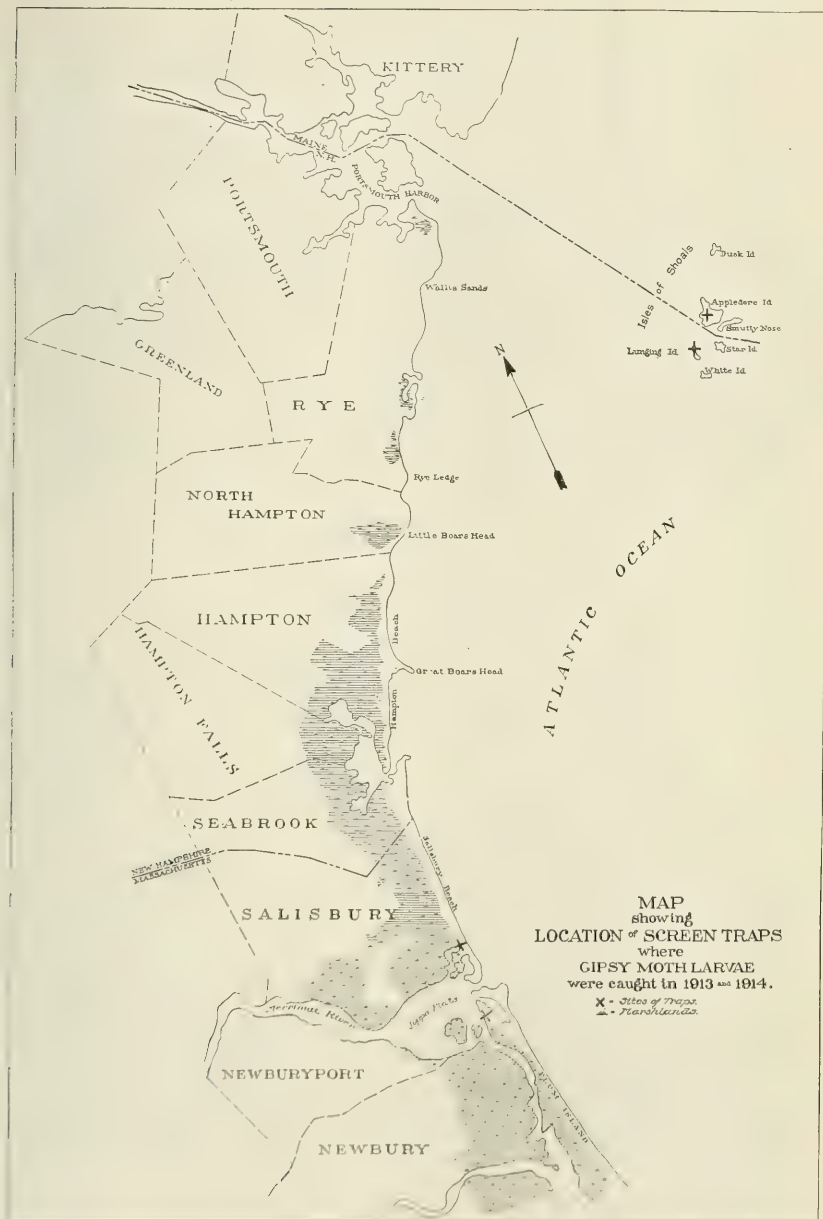
The length of life depended upon the density of the tanglefoot in which they were placed. If the caterpillars in attempting to free themselves became submerged below the spiracles, which often happened in 3 to 5 hours, they died shortly after. As a result, caterpillars lodged in globules of tanglefoot on the screens died in 4 to 6 hours, while those in very thin spots lived 24 or more.

SCREEN EXPERIMENTS AT SALISBURY BEACH, MASS., IN 1913.

April 24, 1913, a large screen (Pl. III, fig. 1), as described, was erected on the edge of the marsh area near the beach, on a site which was 1 mile distant from infested woodlands to the northwest, $1\frac{1}{2}$ miles to the west, and $2\frac{1}{2}$ miles to the southwest. The area to the east, composed of sand dunes, contained small amounts of vegetation, on which gipsy moths could thrive, but this was properly scouted and cleaned for an experiment on reinfestation by the wind.

The temperature, wind direction, and wind velocity were taken each day at alternate hours from 9 a. m. to 5 p. m., and the screen was examined most days when the winds were fair for winds spread from the west. Mr. F. W. Graham was in attendance at this screen and made many of the following observations and notes.

No larvæ were blown on the screen, which was one-fifth mile from the ocean, by winds coming directly from the east. Larvæ were



MAP SHOWING LOCATION OF SCREEN TRAPS WHERE GIPSY-MOTH LARVÆ WERE CAUGHT IN 1913 AND 1914.



FIG. 1.—SCREEN AT SALISBURY BEACH, MASS., WHERE 266 LARVÆ WERE CAUGHT DURING MAY AND JUNE, 1913, AND 96 IN MAY, 1914. SHOWING BEACH AND OCEAN IN BACKGROUND. (ORIGINAL.)



FIG. 2.—SCREEN AT PLUM ISLAND, MASS., WHERE 42 LARVÆ WERE CAUGHT IN MAY, 1914. NEWBURYPORT IN BACKGROUND 2 MILES WEST—NEAREST INFESTED TREE GROWTH IN THAT DIRECTION. (ORIGINAL.)

SCREEN TRAPS FOR WIND-BLOWN GIPSY-MOTH LARVÆ ON MASSACHUSETTS COAST.

borne, however, by northeast and southeast winds from beach infestations 1 mile or more distant. This screen was inspected in May by Dr. Howard and Dr. Paul Marchal.

TABLE II.—*Dates and numbers of newly hatched caterpillars caught on screen, with temperatures, direction of wind, and velocity of wind, at Salisbury Beach, Mass., in 1913.*

Date and time removed.	Number of caterpillars caught.	Maximum temperature.	Minimum temperature.	Average between 9 a. m. and 5 p. m.	
				Prevailing wind direction.	Wind velocity, in miles per hour.
		° F.	° F.		
May 8.....	(¹)	54	49	S. and SE...	11 to 15
May 9, p. m.....	2	62	52	W. and SW...	8 to 11
May 10.....	(¹)	49	44	NW.....	18 to 22
May 11, a. m.....	3	57	50	NW.....	15 to 18
May 12.....	(¹)	60	56	NW. and SE...	8 to 11
May 13.....	(¹)	70	59	SW.....	10 to 13
May 14, a. m.....	19	68	62	NW.....	13 to 17
May 15, a. m. and p. m.....	71	64	49	W. and SW...	7 to 9
May 16, p. m.....	15	44	42	NE.....	8 to 12
May 17, p. m.....	13	54	50	E. and NE...	8 to 12
May 18.....	(¹)	(²)	(²)		
May 19, p. m.....	25	64	58	W. and NW...	18 to 23
May 20, p. m.....	30	66	55	NW. and W...	15 to 20
May 21, p. m.....	10	60	51	SE.....	8 to 12
May 22.....	(¹)	52	48	E. to NW...	6 to 8
May 23, p. m.....	12	58	54	NW., SW., and E.	2 to 5
May 24.....	(¹)	56	52	N. to E.....	7 to 10
May 25.....	(¹)	53	51	E. and SE...	7 to 11
May 26, p. m.....	16	59	57	NW to E....	6 to 10
May 27.....	(¹)	51	48	E.....	8 to 12
May 28.....	(¹)	48	47	NE.....	8 to 11
May 29.....	16	64	53	NW.....	19 to 23
May 30, p. m.....	3	72	64	W. and NW...	17 to 21
May 31, p. m.....	11	76	62	NE to NW...	8 to 12
June 1, a. m. and p. m.....	18	77	62	SE to SW...	16 to 20
June 2, p. m.....	0	72	62	NW.....	16 to 20
June 3, p. m.....	1	79	72	SW.....	15 to 19
June 4, p. m.....	0	62	56	NW. to E....	12 to 16
June 5, p. m.....	1	70	62	E. to S.....	7 to 11
Total.....	263				

¹ No examination.

² No records.

It will be noted from Table II that 266 caterpillars were caught on 450 square feet of wire, and most of these on days when the winds blew from the northwest, west, or southwest, namely, May 14 to 19, May 15 to 17, May 19 to 25, May 20 to 30, etc., while fewer were caught when the wind was from the northeast and southeast. This may be explained by the light infestations 1 mile or more to the northeast and southeast; also it will be noted that winds from these directions along the coast are accompanied by much lower temperatures, at which time the caterpillars spin less actively.

Many of the small larvæ were taken on the posts and crosspieces of the structure; thus of the 25 caught May 19, 18 had lodged in this manner and were living when removed. Others were swinging by threads on the east side of wire, where they had blown through the mesh from the west, the threads having caught in tanglefoot.

The first larva was caught May 9 and the last June 5, although examinations of later date were made. These dates indicate the range of the wind dispersion period for that section in 1913. The distance borne by the wind was 1 mile or more.

Another small experiment was conducted 200 feet from the above screen by attaching to the northwest, west, and southwest sides of a small stable 77 square feet of cotton cloth which was smeared with tanglefoot. This experiment was not started at the beginning of the season, but 9 larvæ were blown into the tanglefooted cloth between May 20 and 31. The object in this experiment was to ascertain the comparative efficiency of tanglefooted wire screen and a solid tanglefooted surface as traps.

CONTINUATION OF SCREEN EXPERIMENT AT SALISBURY BEACH, MASS., IN 1914.

The same screen (Pl. III, fig. 1) as was erected in 1913 was cleaned and retanglefooted for the dispersion season of 1914. The infestation in the woodlands to the westward, owing to the increase of *Calosoma sycophanta* L., *Compsilura concinnata* Meig., and the wilt disease, was less intense during the latter year. The dispersion period was much later and consequently much shorter than in 1913. Examinations were begun about the time the hatching of eggs was first noted in the field. The first caterpillar was caught May 19 and the last May 31 in this location.

The weather records were taken 1 mile south for this point at Plum Island, Mass. (Pl. II), by Mr. C. E. Hood, and were compared with those of the United States Weather Bureau at Boston, Mass., from which they differed very little.

TABLE III.—*Dates and numbers of newly hatched caterpillars caught on screen, with temperature, direction of wind, and velocity of wind, at Salisbury Beach, Mass., in 1914.*

Date and time removed.	Number of caterpillars caught.	Maximum temperature.	Minimum temperature.	Average between 8 a. m. and 5 p. m.	
				Prevailing wind direction.	Wind velocity, in miles per hour.
May 19, a. m.	1	°F. 78	°F. 64	W. and NW....	8 to 12
May 20, a. m.	7	81	66	W. and NW....	2 to 6
May 21, a. m. and p. m.	32	60	53	NE. to SE....	7 to 11
May 22, a. m.	0	60	55	E. and SE....	2 to 10
May 23, a. m. and p. m.	12	78	65	W.....	10 to 23
May 24, a. m. and p. m.	14	78	64	W.....	11 to 16
May 25, a. m.	7	75	61	SW.....	12 to 21
May 26, a. m.	10	89	75	SW. and W....	7 to 20
May 27, a. m.	5	94	79	W. to S.....	4 to 12
May 28, a. m.	1	82	75	NW.....	11 to 20
May 29, a. m. and p. m.	4	66	56	E. and SE....	9 to 17
May 30, a. m.	2	76	60	SW.....	7 to 9
May 31, a. m. and p. m.	1	84	77	W.....	7 to 14
Total	96				

In all 96 larvæ were trapped during the season, most of which were removed on days when the wind blew from the west, southwest, or northwest. The largest catch was removed May 21, at which time the wind blew from the northeast and southeast, but it was evident that most of the larvæ were caught May 20 in the afternoon, as the screen was not examined during that period. There was less source of spread from the northeast and southeast along the ocean shore than from the westward points. On May 21 the temperature ranged from 53° to 60° F., at which time there was reasonable activity among the caterpillars.

One should not fail to note that spread was secured from all directions from which the wind blew except from the east, and the infestation at this point was almost obliterated. No north winds were noted during the hourly observation periods.

SCREEN EXPERIMENT CONDUCTED ON PLUM ISLAND, MASS., IN 1914.

April 14, 1914, a screen (Pl. III, fig. 2) was erected on the edge of the marsh near the Merrimac River. It was of the same size and proportions as that erected 1 mile farther north, at Salisbury Beach. The shrubbery, composed mostly of beach plum, bayberry, wild rose, sumac, poplar, and willow, on the north end of the island, was examined for egg clusters and these were creosoted. This practically obliterated the source of infestation to the eastward of the screen.

The location of the screen (Pl. III, fig. 2) was such that it was 2 miles from infested woodlands across the marshes and Merrimac River to the northwest, west, and southwest. Frequent examinations made it possible to determine the direction from which all the caterpillars came. It is not supposed that all the caterpillars caught during the time west winds prevailed came from the nearest infestations (2 miles), but in some instances 5 miles or more. There was, however, a small infestation on a few roadside willows 1 mile to the southwest, but these were so thoroughly cleaned and tanglefooted in the spring that no caterpillars could be found on them during the dispersion season. The woodland infestation was 1 mile beyond this, totaling 2 miles from the screen.

Mr. C. E. Hood attended the screen, making three or four examinations for larvæ daily from May 10 to June 13. The temperature, wind direction, and wind velocity were recorded hourly each day from 8 a. m. to 5 p. m., inclusive.

TABLE IV.—*Dates and numbers of newly hatched caterpillars caught on screen, with temperatures, direction of wind, and velocity of wind at Plum Island, Mass., in 1914.*

Date and time removed.	Number of caterpillars caught.	Maximum temperature.	Minimum temperature.	Average between 9 a. m. and 5 p. m.	
				Prevailing wind direction.	Wind velocity, in miles per hour.
		° F.	° F.		
May 20, a. m. and p. m.	8	81	66	W. and NW.	2 to 6
May 21, a. m.	4	60	53	NE. to SE.	7 to 11
May 22, a. m.	1	60	55	E. and SE.	2 to 10
May 23, a. m. and p. m.	14	78	65	W.	10 to 23
May 24, a. m. and p. m.	7	75	64	W.	11 to 16
May 25, a. m. and p. m.	5	75	61	SW.	12 to 21
May 26, p. m.	1	89	75	SW. and W.	7 to 20
May 27, p. m.	1	94	79	W. to S.	4 to 12
May 28, p. m.	1	82	75	NW.	11 to 20
Total.....	42				

A total of 42 caterpillars were removed from this trap between May 20 and May 28—a very short season in comparison to the records at Salisbury Beach in 1913. Five of these larvæ were blown on the screen by winds from the east and south, while the remaining 37 came with the winds from the west. Larvæ were caught during the morning of May 20, when the velocity of the wind for that period ranged from 2 to 4 miles per hour, and on the following day, when the temperature ranged from 53° to 60° F.

SCREEN EXPERIMENT ON ISLES OF SHOALS, N. H.

The Isles of Shoals (Pl. II), located 6 miles off the coast of New Hampshire and Maine, was selected as an ideal place in which to establish a trap for tests in long-distance spread. An elevated spot on Appledore Island was chosen and a screen erected in April, 1913. It was not known at that time that Appledore, comprising about 100 acres, was infested, but subsequent scouting in the summer showed that this was the case. This island contains a varied growth of low shrubbery, some of which is very favorable food for gipsy-moth larvæ, but the infestations were slight and covered small areas well scattered over the territory.

The screen was examined at intervals during that year from May 1 to June 3 and 14 first-stage larvæ were removed during that period. Some of these larvæ were alive on removal and were taken on days when the wind blew directly from the mainland, which indicated that many of them came from that source, but there was room for question because the island on which the screen was located in 1913 was later found infested.

To eliminate any possibility of error in drawing conclusions another island in this group, namely, Lunging, was selected for the experiment in 1914. It is the most western of the isles and located so as to

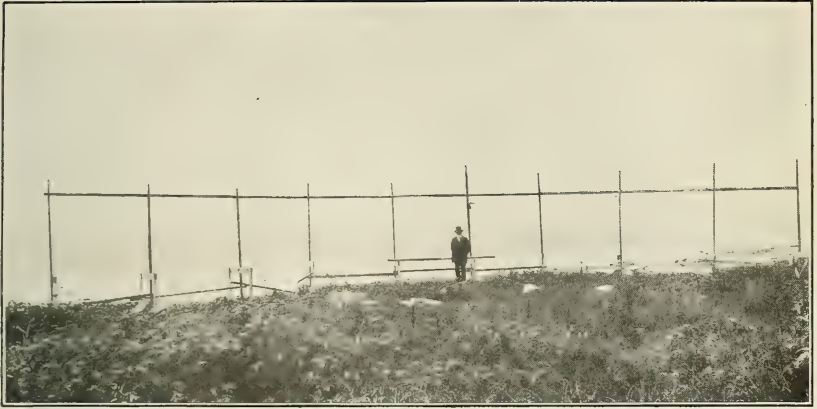


FIG. 1.—SCREEN ON LUNGING ISLAND, ISLES OF SHOALS, N. H., ON WHICH 57 LARVÆ WERE CAUGHT DURING MAY, 1914. OCEAN IN BACKGROUND. VEGETATION IN FOREGROUND IS UNFAVORABLE FOOD FOR THE LARVÆ. (ORIGINAL.)



FIG. 2.—SCREEN ON HOLTS HILL, HENNIKER, N. H., WHERE TWO LARVÆ WERE CAUGHT IN 1914. (ORIGINAL.)

SCREEN TRAPS FOR WIND-BLOWN GIPSY-MOTH LARVÆ IN NEW HAMPSHIRE.

receive the full force of the northwest, west, and southwest winds directly from the mainland. This island is composed mostly of bare rock, with small patches of soil. There is little favorable vegetation for gipsy-moth larvæ, and three careful examinations made in the spring of 1914 revealed no egg clusters.

Four hundred and fifty square feet of wire screen was used, and an extra screen was made of cotton cloth tacked to a frame 40 feet long and 3 feet wide, and tanglefoot applied. It was anchored at an incline on the rocks, facing the west.

On this island there is one cottage which afforded quarters for Mr. Harry L. Blaisdell, who was in constant attendance at the screen (Pl. IV, fig. 1). Arrangements were also made with the United States Life-Saving Service for transportation to and from the islands on their regular trips to Portsmouth, N. H. Mr. Blaisdell recorded the weather conditions hourly from 8 a. m. to 5 p. m., using a compass, thermometer, and hand anemometer. He also examined the screens continuously and made careful notes on the time and wind conditions when each caterpillar was caught, which made it possible to determine the source from which it came. Practically all the larvæ found on the screens were alive, and in most cases they were removed very soon after entanglement.

TABLE V.—*Number of caterpillars caught at Lunging Island, Isles of Shoals, N. H., in 1914, with direction and distance from which they came.*

Date.	Other islands of the Isles of Shoals, E., NE., SE., and S., $\frac{1}{2}$ and $\frac{3}{8}$ mile.	Kittery, Me., NW., 7 miles.	Wallis Sands and Rye, N. H., WNW., 6 miles.	Rye Ledge and Little Boars Head, N. H., W., 7 miles.	Seabrook, New Hamp- shire, and Massachu- setts line, WSW., 11 miles.	Plum Island (north end), Mass., SW., 13 $\frac{1}{2}$ miles.
1914.						
May 20.....	6	1				
May 21.....	6					
May 22.....	1					
May 23.....			8	3		
May 24.....			20		1	
May 25.....	7					9
May 26.....	2					
May 31.....	1					
June 1.....	1					
June 2.....	1					
Total	25	1	28	3	1	9

Sixty-seven larvæ were removed from the screen and cotton cloth between May 20 and June 2. The wind data given in the table were taken on the island, but comparison was also made with the records taken at Plum Island, Mass., 13 $\frac{1}{2}$ miles to the southwest. It was thought that the air currents on the shore of the mainland where most of the small larvæ were picked up would be much changed from their course before reaching the islands, but only slight differences were noted by the two observers during the period.

It will be noted, according to the records taken on Lunging Island, that nine larvæ came from the southwest, that is, from Plum Island, $13\frac{1}{2}$ miles away. The weather records at the latter place indicate that conditions were such that at least 18 of those caught on the screen at Lunging Island came from Plum Island, or more distant points in that direction.

Thirteen and one-half miles is the maximum record for distance that larvæ have been carried by the wind in all experiments thus far conducted by us, yet it is probable that the limit has not been reached. The locations for securing such records, together with suitable conditions with reference to infestations, are rare.

DISPERSION EXPERIMENTS ON THE HILLS OF NEW HAMPSHIRE IN 1913 AND 1914.

In the scouting operations conducted by Mr. L. H. Worthley in the outside territory infested by the gipsy moth, numerous infestations were being found on hilltops. It could not be ascertained whether this spread was the result of the wind, vehicles, or other possible carriers—man or animals. These hills contained woodlands, orchards, pastures, mowings, and roads over which there was more or less travel, making spread possible artificially. Thinning was practiced in these infestations, egg clusters were creosoted, and bands of tanglefoot were placed on the trees to keep the first-stage caterpillars hatching near the ground from ascending the trees, thereby decreasing their chances of spread by the wind.

To investigate the source of these hilltop infestations, one hill was selected in each of four towns in New Hampshire, namely, Andover, Henniker (Pl. IV, fig. 2), Hillsboro, and Troy, and large screens erected thereon as traps for the small caterpillars. (See also Plate VII.) It seemed desirable to know if these colonies were the result of windspread, and whether caterpillars were being carried from hilltop to hilltop, valley to hilltop, or vice versa, so that scouting and control methods could be changed accordingly.

The screens were constructed of $\frac{3}{8}$ -inch mesh poultry wire 3 feet wide. This was stapled to posts set in the form of a T. The posts were about 12 feet high and guyed with No. 13 wire. The wire was fastened in two widths, one above the other, making a screen surface 6 feet wide. The top selvage ranged from 10 to 12 feet from the ground owing to the level of the land. The screens were erected with one wing 35 feet long, facing the north and south, and another, 40 feet long, facing east and west. The total number of square feet exposed to the winds in each screen was 450.

There were known infestations one-third to two miles in all directions from the screens in the foregoing towns, but negative results were

secured on those at Hillsboro and Troy, N. H., the infestations in the neighborhood of which were fewer and at longer distances.

In 1912 several large gipsy-moth colonies were found in Andover and Henniker, N. H. On Beech Hill, Andover, about one-third of a mile from where the screen was erected, over 30,000 larvæ were destroyed in the summer of 1912. This colony and surroundings were carefully treated, so that the infestation was nearly exterminated in 1913 and 1914. All the smaller colonies found in the town also received thorough treatment. Similar conditions prevailed in Henniker.

The screens were examined at periods during the dispersion season of 1913 and 1914. No positive results were secured during the first year, but one living larva was removed from the Andover screen May 27, 1914, at 2 p. m.

May 26, 1914, a dead larva was removed from the Henniker screen and a living specimen June 13, together with the molted skin of a second-stage larva. It is difficult to state from which direction the first larva was blown, but the second came from the northwest or west as the wind blew from those directions during the two days previous.

The 3 first-stage larvæ caught on the Andover and Henniker screens in 1914 proved conclusively that the dispersion among the hills is brought about most extensively by the wind. This is more emphatic when one considers the small air space covered by these traps and the small sources of infestation in these localities.

ALTITUDE EXPERIMENT WITH AVIATION OF SMALL CATERPILLARS.

At the close of the season's work in 1913, after securing some fair records on the distance that larvæ are borne by the wind, it seemed advisable to get data on the possible altitude they reach during their transportation. After numerous inquiries and investigation a suitable place for such an experiment was found in Merrimac, Mass. (Pl. VII). This consisted of the standpipe (Pl. V, fig. 1) for the storage and pressure of the town water. It is located on a small hill 240 feet above sea level, and permission to erect a small wire screen on the top of the tank was obtained from the selectmen of the town.

The tank was 55 feet high from the level of the summit of the hill and a screen of $\frac{3}{4}$ -inch mesh poultry wire was stapled to upright 2 by 4 posts 5 feet long. The top selvage of the wire (Pl. V, fig. 2) was 5 feet above the top of the tank, totaling 60 feet above the ground. The screen was 36 feet long and contained 144 square feet, while the tank was 40 feet in diameter, allowing ample space for the examiner to get around the ends. It was set up so that the sides faced the east and west.

Near the tank were a few low trees consisting of white pine and gray birch; these were cleaned of egg clusters and the trunks tangle-footed in order to prevent the larvæ resulting from overlooked egg clusters getting into the tops of the trees. The country about this hill on all sides is generally infested (Pl. VI), so that almost all winds tempered to 50° F. or above bore caterpillars. The weather data used for comparison with the daily catch here was taken at Plum Island, about 10 miles east.

TABLE VI.—*Dates and numbers of caterpillars removed from screen at Merrimac, Mass., in 1914; also general direction of the wind during the period.*

Date and time removed.	Number borne by west winds.	Number borne by east and south winds.	Direction of wind at time of examinations and a few hours previously.
May 19, p. m.	19	0	NW. and W., 8 a. m. to 5 p. m.
May 20, p. m.	22	0	NW. and W., May 19, 8 a. m., to May 20, 2 p. m.
May 21.	(²)	-----	-----
May 22, p. m.	0	44	NE., E., and SE., May 20, 3 p. m., to May 22, 5 p. m.
May 23, p. m.	8	0	W., NW., and SW., May 23, 8 a. m., to May 27, 10 a. m.
May 24, p. m.	32	0	Do.
May 25, p. m.	2	0	Do.
May 26.	(²)	-----	-----
May 27, p. m.	³ 12	0	Do.
May 27, p. m.	0	³ 6	Changed to S., May 27, 11 a. m., to 5 p. m.
May 28, p. m.	2	0	W. and NW., May 28, 8 a. m. to 5 p. m.
May 29.	(²)	-----	-----
May 30, p. m.	2	0	SW. and W., May 30, 8 a. m., to June 1, 11 a. m.
May 31.	(²)	-----	-----
June 1, p. m.	1	0	S. and SE., June 1, 12 m. to 5 p. m.
June 2, p. m.	1	0	W. and NW., June 5, 8 a. m., to June 6, 5. p. m.
Total.	91	50	

¹ Some of these larvæ were caught before this date, as 7 were dead on removal.

² No examination.

³ Number accredited to different winds estimated owing to changes in direction.

One hundred and forty-one larvæ were trapped on this screen of 144 square feet between May 19 and June 2, inclusive. A few of these undoubtedly were blown on before May 19, as seven of the nine were dead on removal, indicating that the aviation of the small larvæ began probably two or more days earlier in Merrimac than along the seacoast.

With apparently an equal infestation on all sides of this screen one-half mile or more distant, almost twice as many larvæ were trapped as a result of prevailing winds from the west as from the east.

The data secured in this experiment indicate that all winds during the day in a section generally infested bear caterpillars excepting the north, which was not recorded during this period. Considering that practically one larva was caught per square foot 300 feet above sea level, it is only by conjecture that we can estimate the maximum height reached by them and the length of time they remain suspended under average conditions. It is a known fact that large numbers of

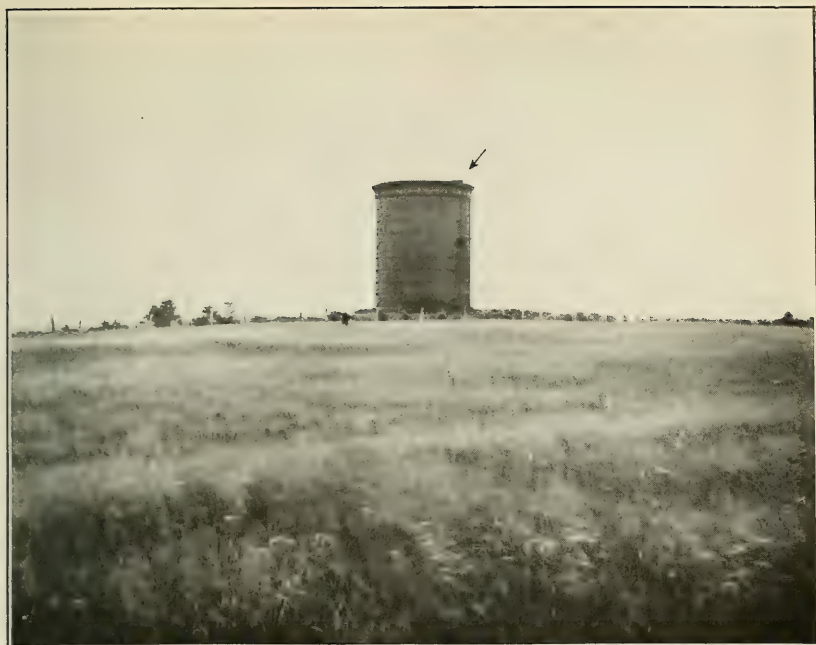


FIG. 1.—SHOWING STANDPIPE, MERRIMAC, MASS. ARROW POINTS TO SCREEN TRAP ON TOP. (ORIGINAL.)

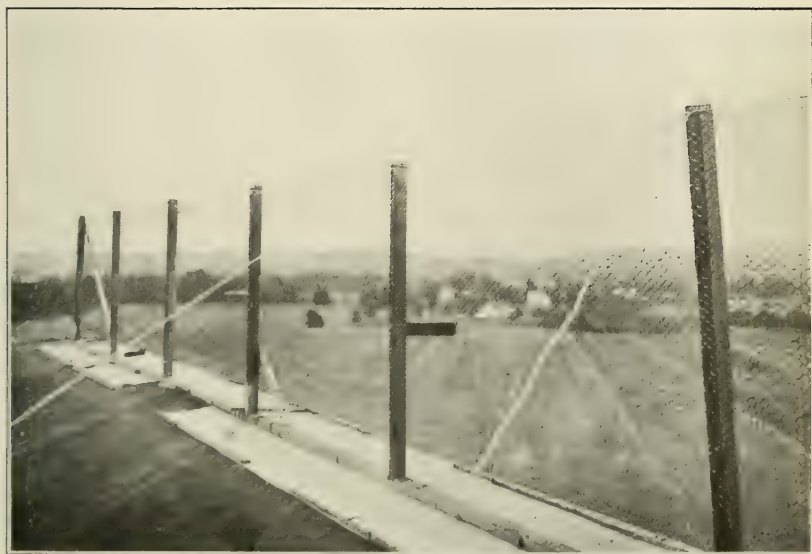
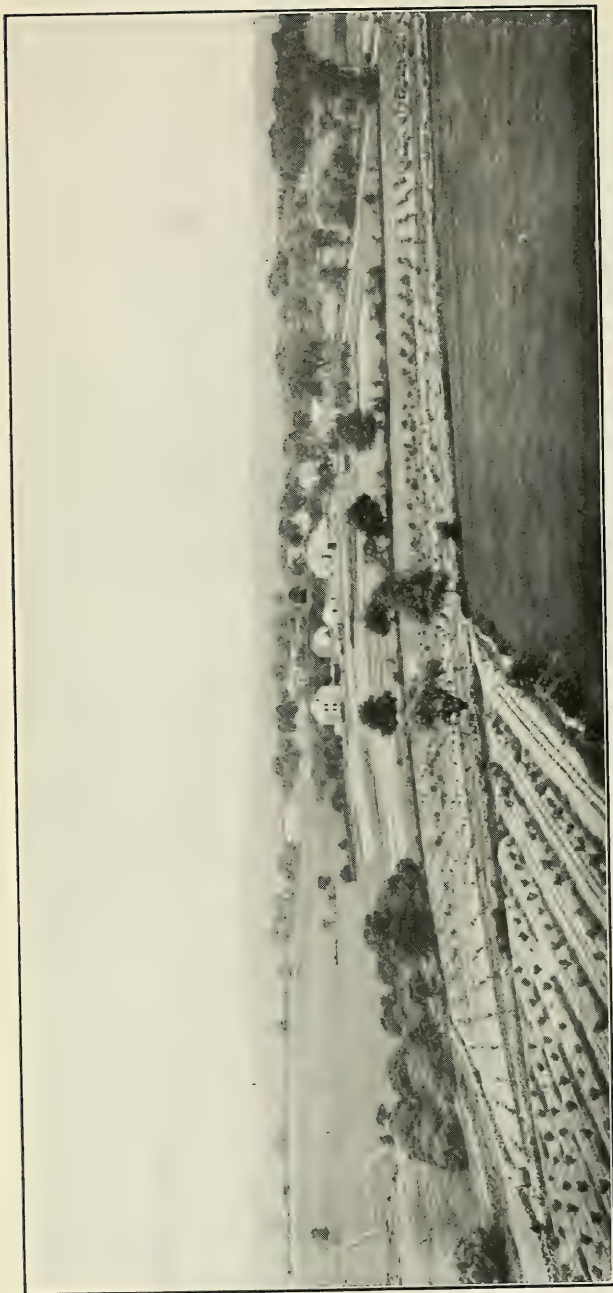


FIG. 2.—SCREEN ON STANDPIPE, MERRIMAC, MASS., AT CLOSE RANGE, WHERE 141 LARVÆ WERE CAUGHT DURING MAY AND JUNE, 1914. (ORIGINAL.)

SCREEN TRAP FOR WIND-BLOWN GIPSY-MOTH LARVÆ, MERRIMAC, MASS.



VIEW FROM TOP OF STANDPIPE, MERRIMAC, MASS., SHOWING SOURCE OF GIPSY-MOTH INFESTATIONS; ALSO YOUNG ORCHARDS WHERE SCATTERING INFESTATIONS WERE LOCATED AS A RESULT OF WIND DISPERSION. (ORIGINAL.)

isolated infestations are scattered in hill and dale over 19,378 square miles of the New England States (Pl. VII), excepting Vermont,¹ and a comparison of such information with the foregoing data at once suggests the source of practically all spread of this species.

OBSERVATIONS ON WIND DISPERSION AT SALISBURY BEACH, MASS., IN 1913 AND 1914.

Salisbury Beach, owing to its separation by extensive marshes from infested woodlands and to the limited amount of favorable food plants for gipsy moths thereon, was selected as a desirable location to be cleaned up and watched for reinfestation. The south end of the beach (Pl. II), $1\frac{1}{2}$ miles in length, was scouted and the egg clusters were creosoted in 1913 and 1914. Beach plum was the predominant shrub growing on the sands and was not fed upon by the caterpillars. Bayberry, wild rose, willow sprouts, balsam poplar, and other small growth thrived to a certain extent and are favored food plants.

The scouting in 1913 resulted in the finding of 144 egg clusters distributed over the beach in a few clumps of shrubbery. The control work was followed up during the summer by frequent examinations for caterpillars, which resulted in their discovery in seven or more places other than where egg clusters were located. From one to six caterpillars were found in small isolated clumps of bayberry and wild rose in no less than six spots near which there were no egg clusters. These patches of favorable food afforded good traps for the newly hatched caterpillars, which were being carried from the infested woodlands 1 mile to the west, as did the tanglefooted screen on which such large numbers were caught the same year.

Seventy-seven egg clusters were found and creosoted in 1914 in the same area as was scouted in 1913. Thus it will be noted that there were slightly more than one-half the number of egg clusters found in 1914 as in 1913, in spite of the rigid control measures practiced during the former year. The location of the beach with respect to the infested woodland across the marshes was ideal for heavy reinfestation each year, and this condition prevails in apple orchards, woodlands, and shade trees that are cleaned within the gipsy moth infested area and become reinfested annually by means of the wind.

OBSERVATIONS ON ISOLATED TREES AND YOUNG APPLE ORCHARDS FOR REINFESTATION.

Twelve isolated trees in the midst of cultivated fields and mowings were selected in the early spring of 1914; these were cleaned of egg clusters, trunks tanglefooted, and later examined for reinfestation by the wind. These trees were selected in towns about Merrimac, Mass.,

¹ During the winter of 1914-15 a few small infestations were discovered in Vermont.

where there was a general infestation. Some of them were later discarded owing to the discovery of overlooked egg clusters that had hatched. On the trees retained there were from 2 to 8 and in one case 11 large caterpillars above and below the tanglefoot, indicating that there was reinfestation by the wind. The top of a medium to large sized apple tree would offer more resistance to the wind than did the screen on the Merrimac standpipe, upon which was lodged approximately one first-stage caterpillar to every square foot of wire exposed.

Some further observations confirming these conclusions were made by Mr. C. E. Hood in July, 1914, in two young apple orchards in Merrimac (Pl. VI) and West Newbury, Mass. These orchards were 2 and 4 years old, respectively, and clean cultivation was practiced in them. A large number of the trees were examined in the center of these orchards, which were in some cases 500 yards from the nearest infestations on larger trees. Thirty-four large larvæ were found in selected areas of the two orchards, not more than one of which appeared on a single tree. No egg clusters could be found, and it was concluded that the infestation was due to windspread.

Mr. J. V. Schaffner, jr., has also reported a similar incident from Dover, Mass.

SMALL LARVÆ BLOWN INTO THE OCEAN ANNUALLY FROM INFESTED WOODLANDS NEAR THE COAST.

At the rate of 266 first-stage larvæ caught on 450 square feet of tanglefooted wire at Salisbury Beach in 1913 (being located 1 mile from the nearest infested woodland), a basis is given for estimating the huge numbers borne into the ocean each year. At the same ratio a continuous screen 1 mile long and 6 feet high would have caught 18,726 larvæ. Judging from the altitude, 300 feet above sea level, where quantities were caught at Merrimac, Mass., it is apparent that this number should be fifty times as much, or 936,300 per mile. There is now upwards of 450 miles of coast line infested in New England (Pl. VII), and figuring that general spread by wind occurs over one-half of this distance, the ocean swallows up annually over 210,000,000 small larvæ. The number is probably much greater than is here indicated, as it is not known how many of the small larvæ passed through the wire meshes of the screen which is used as a basis for these figures.

These calculations, which are partly theoretical, serve to indicate what might have been the result with regard to the area infested had the moth first been introduced 100 miles farther westward than Medford, Mass. It also emphasizes the necessity of keeping this moth confined to New England territory, if rapid and general spread over the United States is to be prevented.

FEEDING OF LARVÆ PRIOR TO DISPERSION BY THE WIND.

Several of the first-stage caterpillars of various sizes caught on the screens during 1913 and 1914 were selected and examined for the presence of plant cells in the alimentary tract. As all caterpillars blown any reasonable distance by the wind are newly hatched, first-stage specimens, it is impossible to ascertain from a superficial examination which have taken food and which have not. Before the examinations were made it was necessary to fix the material, stain with eosin and methylene blue, section with a microtome, and mount on slides, and this work was performed at Bussey Institute, Harvard University, under the direction of Dr. R. W. Glaser of the Bureau of Entomology.

Caterpillars were selected during the two seasons which had been borne by the wind a distance of 1, 2, and 6 or more miles, respectively, from the nearest source of infestation. Results were as follows:

TABLE VII.—Percentages of small caterpillars having fed which were caught on screens during 1913 and 1914.

Year.	Locality and distance carried by wind.	Number of caterpillars that had fed.	Number of caterpillars that had not fed.
1913.....	Salisbury Beach, Mass., 1 mile from infested woodland.....	13	7
	Isles of Shoals, N. H. Infestation in brushland around screen.....	1	0
1914.....	Plum Island, Mass.; 2 miles from infested woodland.....	2	5
	Isles of Shoals, N. H.; 6 miles or more from infestation on the mainland to the westward.....	7	8
	Merrimac, Mass.; $\frac{1}{2}$ to 1 mile from heavy infestation in all directions..	0	2
	Total.....	23	22

Of the 45 small caterpillars prepared and examined during the two years that experiments were conducted, 23, or 51 per cent, had consumed a very small amount of food, while the remainder, 40 per cent, showed no signs of it.

COMPARISON OF WEATHER DATA BETWEEN PROVIDENCE, R. I., AND AMHERST, MASS., WITH REFERENCE TO DISPERSION IN 1913.

The period in which first-stage larvæ were borne by the wind in 1913 in eastern Massachusetts was from May 9 to June 5, inclusive. After comparing the hourly wind direction from 7 a. m. to 6 p. m. when there was no rain and the temperature was 50° F. or above at Providence, R. I.,¹ and Amherst, Mass.,¹ one notes a slight difference in the total wind movement in the various directions. For instance, in Providence the wind blew from the northwest 92 hours, from the

¹ The weather records at Providence were secured from the office of the U. S. Weather Bureau, and those at Amherst from the Experiment Station.

north 17, from the northeast 22, from the east 3, from the southeast 51, from the south 37, from the southwest 1, and from the west 9 hours during the foregoing period. In Amherst, Mass., it blew for the same period from the northwest 50 hours, from the north 51, from the northeast 9, from the east 2, from the southeast 30, from the south 31, from the southwest 3, and from the west 46 hours.

Providence was first found infested by the gipsy moth in 1901, and during the scouting season of 1913-14 egg clusters were found as far west as Woodstock, Pomfret, and Brooklyn, Conn.—a distance of 36 miles, or an average spread of 3 miles each year. It is apparent that this general infestation was not accomplished by direct east winds, as there are few recorded each year at the proper period, but by a combination of northeast and southeast winds transporting the larvæ in a southwesterly and northwesterly direction from 1 to 10 miles, thus gaining an average of 3 miles each year directly west.

Although this insect has not yet reached Amherst, Mass., in its general sweep across the country, it occurs within a few miles to the eastward. A perusal of the wind records for the dispersion period of 1913 shows three times as many hours of north winds and about one-half as many northeast and southeast winds combined as are recorded in Providence, R. I. The total movement of northwest and west winds, which blow the larvæ back into the infested territory each year, is practically the same in the two localities.

From this data it appears that the increase in the amount of north winds and the decrease in combined northeast and southeast winds at Amherst, when compared with the wind records at Providence, may result in a somewhat more rapid southwestern advance of the insect if it becomes established in the Connecticut Valley. More rapid southern and western spread is likely if the infestation reaches the Central States.

SPREAD OF THE GIPSY MOTH IN NEW ENGLAND.

The gipsy moth was introduced at Medford, Mass. (Pl. VII), in 1869, from which point it has spread gradually over large areas in Massachusetts and other New England States, excepting Vermont.¹ Small infestations have also been located in New York, New Jersey, and Ohio, but these colonies are fast being exterminated. Extensive efforts to prevent spread have been carried on in Massachusetts by the State since 1890, with suspension of appropriations and efforts only from 1900 to 1905. Other infested States have appropriated smaller amounts which have aided in the suppression work. Congress began making appropriations in 1906, and these annual sums have been expended to prevent spread and help control of the gipsy moth and the brown-tail moth.

¹ See, however, footnote on p. 17.

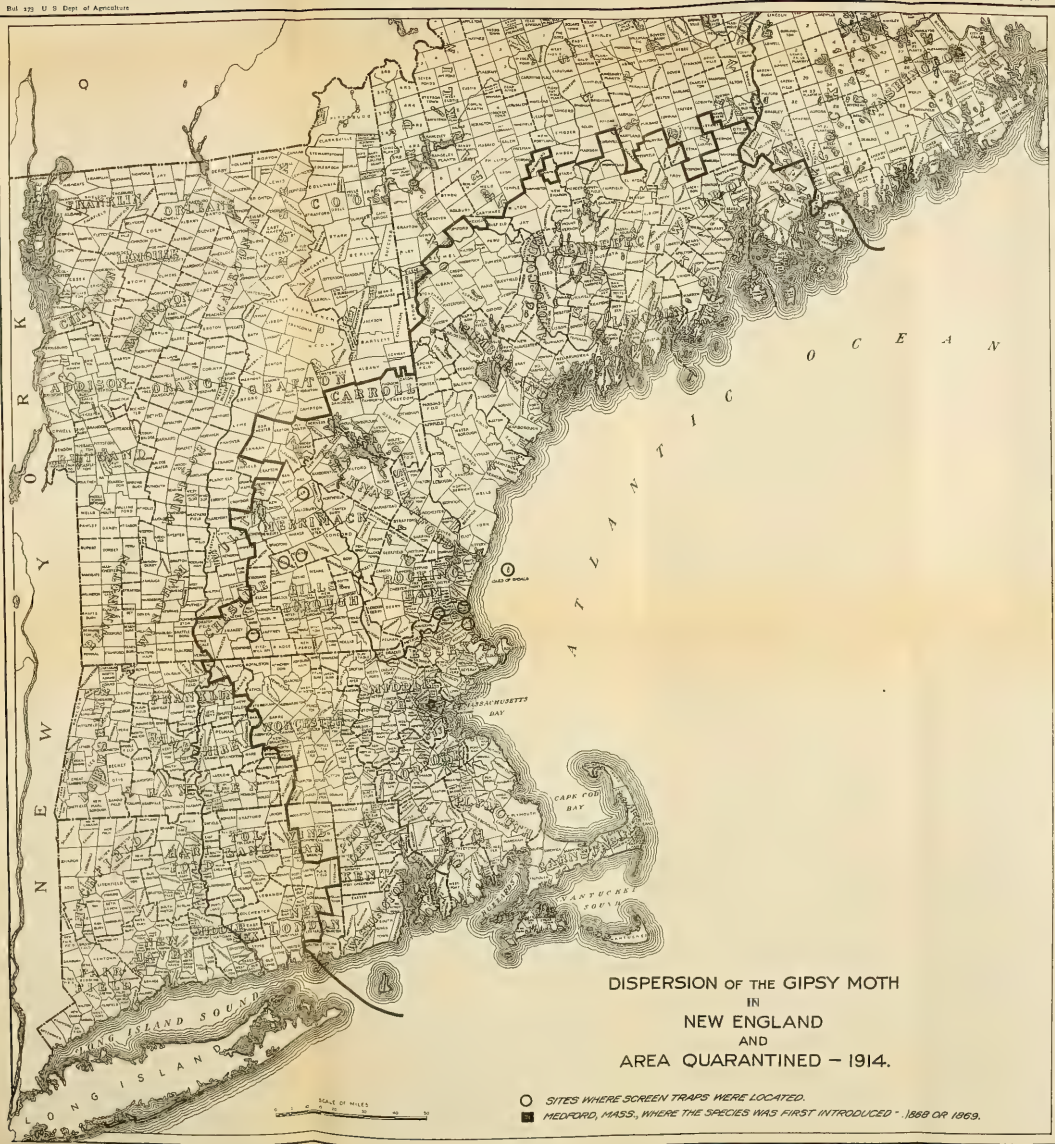


Table VIII is here presented to show the annual advance of the moth before and after control was attempted. This indicates that the winds are chiefly responsible for the present conditions.

TABLE VIII.—*Spread of the gipsy moth in various directions by series of years from five years after its introduction at Medford, Mass., to 1914.*

Periods of years.	NE.	N.	NW.	W.	SW.	S.	SE.	Average spread per year by periods.
	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles per year.</i>
1875-1890.....	15	10	5	10	6	4	3	0.5
1891-1899.....	5	4	5	4	4	5	4	.5
1900-1905.....	27	11	12	10	12	14	62	3.5
1906-1909.....	41	60	25	19	15	16	11	6.7
1910-1914.....	114	16	28	15	24	26	0	6.4
Total.....	202	101	75	58	61	65	80	.....
Average for 40 years.....								2.3
Average spread per year in various directions.....	5	2.5	1.9	1.5	1.5	1.6	2	

It will be noted that the spread from the original center was very slow, averaging only 0.5 of a mile per year up to the beginning of the campaign in 1890. It was then held in control for a period of about nine years, during which time there was very little advance into new territory. The conditions in the old infested area were also much improved. This shows the necessity for keeping the moth under complete control if windspread is to be prevented. During the period from 1900 to 1905, when no work was being done, the moths spread at the rate of 3.5 miles per year. This had increased to 6.7 miles per year from 1906 to 1909, but this ratio has decreased to some extent in the last period up to 1914, inclusive.

The greatest distance gained in various directions has been to the northeast, an average of 5 miles per year for 40 years, which is the result of the favorable southwest winds. The combination of southeast and southwest winds during the dispersion period has carried the larvæ northward at the rate of 2.5 miles per year. The spread to the west, southwest, and south was accomplished at a slower rate, owing to the less favorable winds blowing in those directions.

SUMMARY.

In 1913, as a result of the several experiments conducted by using tanglefooted screens and cloth for traps, there were caught on 977 square feet 289 first-stage larvæ which had been borne by the wind one-eighth to 1 mile or more. In 1914 there were removed from 1,614 square feet of sticky surface 346 larvæ which had been blown from one-eighth to 13½ miles or more, as verified by the wind records taken at or near those points. Three larvæ were also taken from two large screens on the hills in New Hampshire during 1914.

Considering the great numbers of larvæ taken in these experiments, there can be no doubt that the wind is almost wholly responsible for the general spread of this insect in New England, notwithstanding the fact that many of the former publications teem with explanations of possible accidental or artificial spread by man and animals. The recent establishment by the Federal Horticultural Board of a quarantine on lumber products, Christmas trees, nursery stock, and stone moving from the infested territory, until inspection has been made, has greatly relieved the danger of a general distribution of the gipsy and brown-tail moths over the United States, but the sources of dispersion of the gipsy moth by the wind can only be lessened by the effectiveness of the parasites and predaceous enemies, together with hand methods of control. To prevent continual spread by the wind into new territory the badly infested areas near the border must be brought under control either by natural enemies, or hand methods, or both. Natural enemies, however, are now playing an important rôle in the control of this insect in the greater area of the inside infested territory.

The larvæ are sufficiently active and allow themselves to be transported by the wind at temperatures of 55° F. and above, and have been caught at wind velocities varying from 2 to 23 miles per hour, although more active spread takes place when the temperature ranges from 65° to 85° F. and when the velocity reaches 8 miles or more per hour. Larvæ are removed from their support and carried by sudden gusts of wind, whether they spin or not, when the temperature reaches 50° to 55° F., at which temperatures they often start crawling.

The records also show that larvæ have been caught at times when winds were blowing from all directions except the north—only a very few coming from the east, but the location of the screens along and near the coast materially affected this condition. By far the larger numbers were borne by combinations of the west winds as indicated on the screen at Merrimac, Mass., which was surrounded by a general infestation.

The general progress of the species since its establishment at Medford, Mass., at the rate of 5 miles per year to the northeast and at the rate of 3 miles per year westward from Providence, R. I., since its first appearance there in 1901 tends to verify the data that have been collected in connection with the screen experiments.

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WM. A. TAYLOR, Chief

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FACTORS GOVERNING THE SUCCESSFUL SHIPMENT OF RED RASPBERRIES FROM THE PUYALLUP VALLEY.¹

By H. J. RAMSEY, *Pomologist in Charge of Fruit-Handling and Storage Investigations, Office of Horticultural and Pomological Investigations.*

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INTRODUCTION.

Berry growing is the leading horticultural industry in the Puyallup Valley, Wash., and is rapidly increasing in importance in other sections of that State and in Oregon and California. The growth of this industry, as well as the prosperity of the community, in the Puyallup Valley especially, is dependent largely on the extension and broadening of the marketing zone for fresh berries. The carrying and keeping qualities of the berries produced and offered for shipment determine the territory and markets that can be profitably reached. Under the ordinary and usual methods of handling and refrigeration 2,000 miles has been the limit of successful shipment

¹ B. B. Pratt and A. W. McKay, formerly Pomologists in Fruit-Handling and Storage Investigations; S. J. Dennis, Refrigeration Technologist; G. H. Crawford, formerly Assistant Refrigeration Technologist; and G. W. Dewey and J. F. Fernald, of the Office of Horticultural and Pomological Investigations, were actively associated in the prosecution of these investigations.

NOTE.—This bulletin is of interest to growers and shippers of berries generally, and especially to shippers of red raspberries, who are required to meet special problems.

for red raspberries, and oftentimes considerable deterioration and decay occurred at this or lesser distances.

The markets for fresh berries could not profitably be extended without better keeping or carrying qualities. Many of the leading growers have felt that possibly changes in the methods of handling and refrigeration would materially improve the carrying quality. In response to urgent requests from the industry, investigations of the relation of methods of handling and refrigeration to decay and deterioration of Puyallup Valley red raspberries in transit to distant markets were included in the fruit-handling and storage investigations of the Bureau of Plant Industry. The experimental work was carried on during the shipping seasons of 1911 and 1912, and to a



FIG. 1.—A red-raspberry yard at Puyallup, Wash.

limited extent during the season of 1913. Red raspberries were used in the experimental work almost exclusively, although occasional lots of loganberries and strawberries were included during the season of 1911.

THE BERRY INDUSTRY OF THE PUYALLUP VALLEY.

The methods of handling red raspberries are so closely associated with those of growing and of training that it seems desirable to give a brief description of the berry industry as developed in the Puyallup Valley, Wash.

The berry industry in this valley is centralized largely around Puyallup and Sumner, in Pierce County, in the Puget Sound country

of western Washington. The region is one of abundant rainfall, relatively cool summers, and mild winters, and originally was covered with forests of gigantic evergreens. The rains are most abundant during the winter months but are frequent during June, July, August, and September, and are one of the principal factors that determine the season's fresh-fruit shipments. If rains are continuous or frequent, with little or no sunshine, the berries do not mature properly, lack firmness, are soft and full of moisture, and consequently are poor shipping fruits. During 1911 practically all of the red raspberries produced in the valley could have been shipped fresh,



FIG. 2.—Red raspberries at Sumner, Wash., planted in rows, showing the separation of new canes from those in bearing, in order to facilitate picking.

as there were few rains and much dry, sunny weather. In 1912 approximately only half the crop was shipped fresh, the remainder, being too soft for shipment in a fresh state, being put up in barrels and cans.

During the season of 1912 the Puyallup and Sumner Fruit Association, handling at that time approximately 95 per cent of the berry crop of the valley, shipped 270 cars of fresh berries of 545 crates each. Of these 123 were red raspberries, 72 blackberries, 35 strawberries, and the remainder currants, loganberries, gooseberries, etc. The cannery receipted for 1,251,630 pounds of red raspberries, 3,424,874 pounds of blackberries, and 318,000 pounds of strawberries.

The two principal commercial varieties of red raspberries are the Cuthbert and the Antwerp. Of the blackberries the Evergreen, Snyder, Kittatinny, Lawton, and Himalaya are the leading varieties. The Cumberland black raspberry, the loganberry (a hybrid between the Antwerp red raspberry and the Aughinbaugh blackberry), and the Phenomenal (similar to the loganberry) are grown to some extent.

The recent remarkable growth and development of the industry in this valley is due largely to the formation and successful operation of an effective cooperative marketing association. This association some years ago purchased a cannery, which is now operated



FIG 3.—Red raspberries at Puyallup, Wash., grown in continuous rows in accordance with the upright system of training.

as part of the cooperative enterprise. This plant has been greatly enlarged and improved, and more recently a second one has been built. These cooperatively owned canneries serve as the balance wheel of the berry-growing industry in the section. Without them the growers would be in a very precarious state, as through these canneries they are able to dispose of all berries that for various reasons can not be shipped fresh at a profit. During periods following protracted rains, when berries are too soft for shipping, they are utilized for canning purposes and are not a total loss to the grower, as would necessarily be the case without canning facilities. The association has now over 1,500 members, having individual

plantings ranging from a few plants on a city lot to 15 or more acres.

The average berry yard consists of a few acres planted to different varieties of berries, usually half or more planted to red raspberries.

METHODS OF GROWING RED RASPBERRIES.

There are almost as many different ideas of how the red raspberry should be planted, pruned, and trained as there are growers. The most common practice in the Puyallup-Sumner district at the present time is to plant the red raspberries in rows from 6 to 8 feet apart,



FIG. 4.—Red raspberries at Sumner, Wash., trained in accordance with the upright system. All surplus canes have been cut out of the hills and all the remaining canes topped.

either in continuous rows with the plants a few inches apart or in hills $1\frac{1}{2}$ to 3 feet apart in the row. (Figs. 1 and 2.) The hills in each row may have from three to nine canes, depending upon the strength of both soil and cane and the grower's preference. The hill system, with plants in hills about 6 feet apart each way, is occasionally used, but is becoming obsolete.

Where grown in rows, the methods of training and pruning may be roughly classed under four systems, as follows: (1) Upright, (2) weaving, (3) divided row, (4) Strebrow. While there are a great

many others, the ones mentioned or modifications of these are most commonly employed and have been found to be most practicable and profitable.

In the upright system, as illustrated in figures 3 and 4, the old canes are trained between the wires which serve to hold them together and in place. The new canes come up among the old ones or else grow on the ground. The posts which support the wires are about 7 feet in length, set 5 feet above ground at from 30 to 50 feet apart. In this and other systems the wires may be attached directly to the posts or to crosspieces or arms, the wires being all the way from 10 to 16 inches apart. Either one or two sets of wires are used, the top wires being placed from 4 to 5 feet from the ground, the second set from 24 to 30 inches.



FIG. 5.—Red raspberries trained in accordance with one of several systems in use at Sumner, Wash. Topping is not practiced in this system.

The weaving system may be used with either one or two sets of wires. Where two are used the old canes are wound three or more at a time along one of the top wires, the lower wires being used to hold the new canes in place and out of the way of the old ones. There are a great many variations in this system, from those having only one wire along which to wind the old canes and with none to hold the new ones off the ground and free from the old canes to another method where the canes are not woven in as above described but are arched over the top wire two or three at a time and tied to the lower wire, the lower wires in such cases being about 48 inches and the top wire 60 inches from the ground. Several variations in the weaving system are shown in figure 5, where the canes are all woven together three or more at a time along the top wire, in figure

6, where they are woven in a similar way except that they are tied again to the adjoining canes, and in figure 7, where they are wound over a top wire and tied to a lower wire.

In the divided-row system the wires are arranged essentially the same as in the upright continuous-row system, with the top wires at 5 feet from the ground. The old canes are separated and half of them tied or otherwise held in place along one wire, and the remaining half tied to the other wire, leaving space between the wires for the new canes. This system, in a way, has several advantages, in that topping can be practiced and the new canes can be held



FIG. 6.—Red raspberries trained in accordance with a modification of the weaving system, at Sumner, Wash. The canes, after being bent over and twisted around the top wires, are tied to adjoining canes below the wires.

separate and free from the old canes, permitting easier picking and harvesting. One good way of holding the canes in place is to bring the old canes outside the top wire and then to have loose wires outside of these which can be lifted into slots just above and slightly out from the original wires in such a way that the canes are held between the two. This system is illustrated in figure 8.

In the Streblov system the rows are usually about 8 feet apart, running north and south, with hills 30 inches apart in the row. The

posts are set solidly just to the east of the row. A wire is fastened to the post about 40 inches from the ground on the side toward the row and another wire about 52 inches from the ground on the east side of the post. The old canes are securely tied to the lower wire at 3 or 4 inches apart. The upper wire supports the weight of the canes when loaded with foliage and berries. The canes are topped at about 6 feet. A second wire, about 40 inches from the ground, is strung on crosspieces or on the posts on the west side of the row and serves to hold the new canes free from the old ones and off the

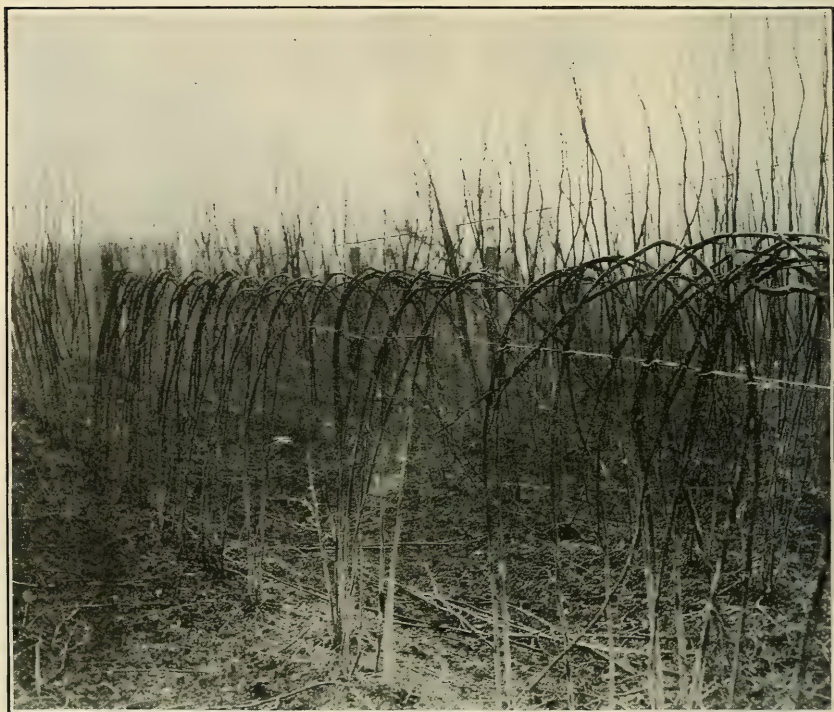


FIG. 7.—Red raspberries trained in accordance with a modification of the weaving system, in which topping can be practiced if found to be desirable. The canes are looped over the top wire and tied to one lower down.

ground. This system has some advantages, in that the canes can be cared for very easily after they are once tied in place and the bearing canes are all on one side of the row, where picking is easy and unhampered by new canes. The canes also lean toward the east, which is considered desirable, and at picking times they shade both fruit and pickers. This system, however, requires more work in training. The rows must be farther apart, and some claim that the yield is somewhat reduced because of the smaller number of canes per

acre. The heavy weight on one side of the post makes it necessary to set the posts deeper or to have them closer together than in other systems. Where hop poles or rails are available at a low cost they are often used in place of the upper wires, the rails bearing the weight of the loaded canes thus providing a larger surface and reducing the danger of having the canes break at this point. The Streblow system is partially illustrated in figure 9. In this case rails are used instead of wires.



FIG. 8.—Red raspberries trained in accordance with the divided-row system, the canes being tied to wires on either side or held in place by an outside wire. Topping may be practiced, if desired.

There is also considerable diversity of practice as regards topping and cutting out the old canes. Some growers cut out the extra canes in the fall, while others leave them until spring. In most cases the canes that are left are usually topped to about 5 or 6 feet in the spring; that is, in the systems of training that permit topping. In some of the weaving systems topping is obviously out of the question. The soil is given rather shallow cultivation during the growing season and the fields are kept clean of weeds until picking time. Nearly all growers fertilize rather heavily, using manures of various kinds in addition to moderately heavy applications of potash.

There is a general belief that potash makes the berries firmer and betters the keeping and shipping quality, and therefore this one element is seldom omitted.

Before the harvesting season commences the growers usually go through the patches and cut out a considerable portion of the new canes and separate the bearing canes from the new ones in order to facilitate picking. The harvesting of berries is facilitated also to a considerable extent by various methods of training, some of which have already been described. Proper training methods, the cutting

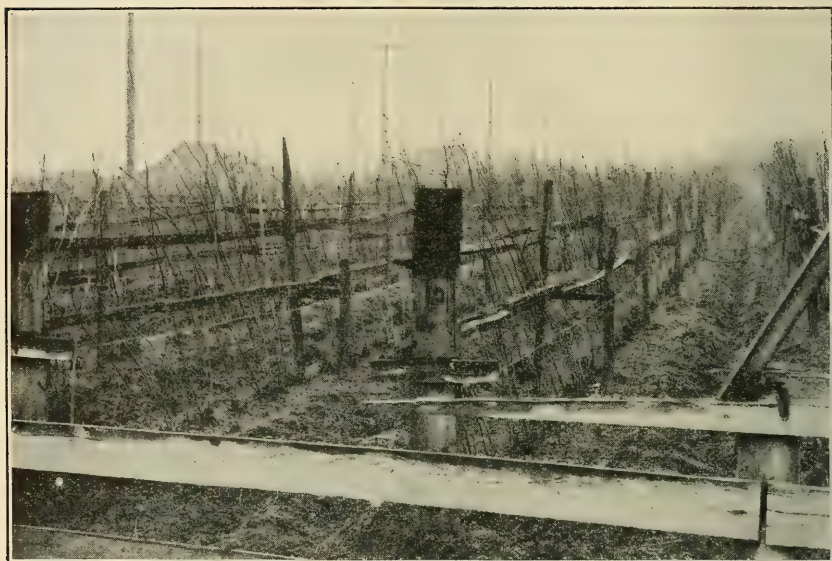


FIG. 9.—A yard of red raspberries trained in accordance with the Streblov system, using rails instead of wires for holding the bearing canes.

out of surplus new canes, and the separation of the remaining ones from the bearing canes prior to harvesting greatly lessen the liability to rough handling and injury in picking.

HANDLING AND SHIPPING RED RASPBERRIES.

The first shipments of red raspberries are usually made about the middle of June, but car-lot shipments are seldom made until the latter part of June or the first of July. The earlier berries are shipped by express, either in crates to near-by cities or in pony refrigerators to Spokane and Montana markets. Later in the season, when car-load shipments commence, usually only such markets as Spokane and others within about the same distance are supplied with raspberries in these pony refrigerators. The berries shipped in this way during

the car-lot season are, as a rule, too ripe to stand long-distance shipment.

PICKING.

The picking is done by men, women, and children, most of whom come from neighboring towns and cities and camp during the harvesting season in the various yards where they are doing the picking. They usually remain until the end of the blackberry season, sometime in September. Some of these people return from year to year, but most of them have had no previous experience. This results in some very poor work as regards both sorting and handling. Each



FIG. 10.—Picking red raspberries at Sumner, Wash. Note the rank growth of new canes.

picker is provided with a 2-cup carrier attached to the waist and when the cups are full they are transferred to 6-cup field carriers provided with handles. (Figs. 10 and 11.) These 6-basket carriers when filled are carried to the receiving sheds, where the berries are sorted and crated. (Fig. 12.) Usually each picker is assigned to a particular row or rows and is held responsible for the harvesting of a certain portion of the row or yard. A foreman or the grower supervises the picking, instructing each picker as to the kind of berries to be picked and how to pick them. At the receiving shed the grower or receiver does more or less sorting by cups, placing the cups containing what are considered shipping berries into shipping

crates and cups with berries too ripe for shipping into cannery crates. The shipping quality is determined by the appearance of the fruit in the box as regards its degree of ripeness and firmness, the fruit never being emptied out for resorting or grading. The final determination of the shipping fruit is, however, made by the association inspectors, and it is not unusual for berries put in shipping crates by the grower to be rejected and sent to the cannery when inspected at the association receiving station.

HAULING AND DELIVERY.

The berries are nearly all delivered at Puyallup or Sumner, a small proportion at North Puyallup, Auburn, and other stations.



FIG. 11.—Picking red raspberries at Sumner, Wash., in a yard in which the new canes have been gathered together in the middle of the row in order to facilitate picking operations.

They are seldom hauled more than 6 miles, and the greater portion less than 3. The wagons used for hauling are of various sizes and types, depending on the quantity of berries and the distance they have to be transported. Large drays provided with good springs are oftentimes used to haul berries from considerable distances for several growers. Usually each grower hauls his own berries, and in nearly every case wagons or carts with springs are used for hauling. Many of the growers living within the city limits or close by take their berries to the canning or receiving stations in 2-wheeled hand carts. Figures 13 and 14 give a good idea of the different

types of wagons and carts used for hauling berries to the cannery and receiving stations. Deliveries are made oftentimes three or more times a day from near-by growers, but usually only once by the more distant ones. Every grower aims to bring all the berries picked during the day to the receiving stations in time to be loaded into the refrigerator cars for shipment on the evening of that day. Each grower is known by a certain number, which must be stamped on all shipping crates brought in, and all berries delivered are credited to his number. shipping berries by number of crates and canning berries by weight.



FIG. 12.—A receiving shed at Puyallup, Wash., where berries are sorted by cups into shipping and canning crates.

These practices are expensive of time and equipment and suggest the need of a cooperative plan for hauling the product. It would seem practicable to devise an effective plan which would conserve the time of the grower as well as simplify the work at the receiving station.

GRADING.

Berries intended for shipment are inspected before they are loaded into the car and are separated into various grades, the grading being based on their degree of maturity, firmness, and the care shown in

picking. (See fig. 15.) The berries run fairly uniform throughout the crate, and the inspection is made by lifting up one end of the cover and at a glance deciding on the general condition of the berries as they appear in the top layer. There are four established grades, as follows:

D.—Stock that can be shipped 2,000 miles or more.

M.—Stock of such character and maturity that it can be safely shipped more than 1,000 miles.

H.—Stock which because of faulty handling or overripeness must be consumed in 24 hours. Such stock is used for local express shipments in pony refrigerators to near-by points.

A.—Stock too soft and ripe for anything but canning.

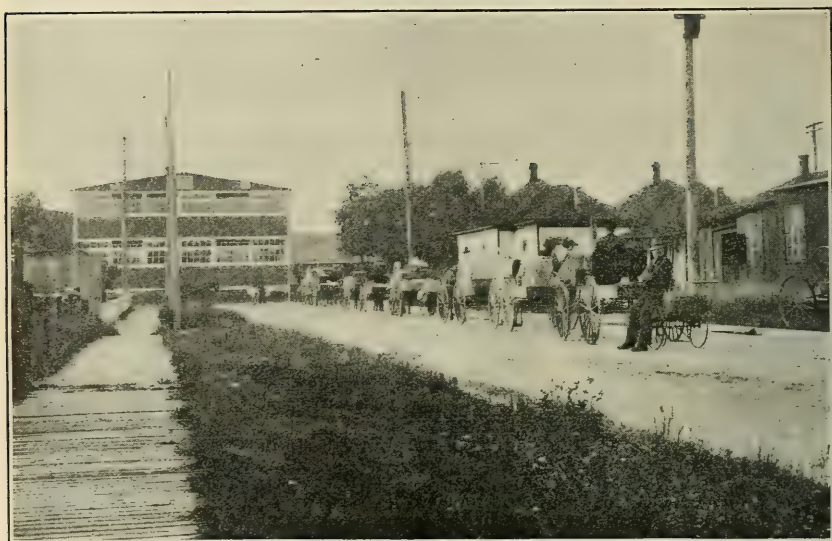


FIG. 13.—Growers waiting in line at Puyallup, Wash., to deliver the day's pick of red raspberries at the cannery or receiving station. Note the various types of wagons and carts in use.

SHIPPING AND MARKETING.

Red raspberries and other berries from this section are shipped by express in crates to near-by cities, like Seattle, in pony refrigerators to markets as far distant as Spokane, Wash., and Missoula, Mont., and in full carload lots in express refrigerator cars as far east as Minneapolis, Minn. Before and after the car-lot season, pony refrigerators are shipped to a greater number of markets and to greater distances than during the car-lot season. Where berries are shipped in crates, not in carload lots, no refrigeration is possible in transit, and this necessarily limits the distance to which they can be shipped in good condition. The crate ordinarily used holds 24 cups in 2 layers of 12 baskets each, and has a middle partition board.

The removable veneer used to separate the top and bottom tiers is fitted into notches cut into the end and middle partition. The pony refrigerator used in this section holds 54 cups in 6 layers of 9 cups each. (See fig. 16.) An ice pan, with drainage, is placed in the top of the carrier, the refrigeration provided being in proportion to the capacity and the quantity of ice in the ice pan. This method of shipment is utilized throughout the season to supply markets at a considerable distance that can not handle full carload lots and that can not be reached without the utilization of refrigeration.

During the main part of the season most of the berries are shipped in express refrigerator cars. These cars are attached to regular fast passenger trains and go through on passenger schedules. The cars



FIG. 14.—Delivering red raspberries at the receiving station at Puyallup, Wash., types of vehicles ranging from carts to large drays and express wagons being used for hauling.

are fully iced at least 12 hours before loading, and after they are fully loaded from 100 to 200 pounds of salt is mixed in with the crushed or broken ice in each bunker. At icing stations the cars are re-iced and may also be resalted. While salt melts the ice more rapidly, it supplies more refrigeration than would be the case if no salt was used. Every effort is made to get all of the fruit of a day's picking into refrigerator cars as soon as possible and to start the cars on the same day or evening that the berries are picked and loaded. The standard load for all except Canadian points is 545 crates, loaded 8 and 9 high in rows of 5 across the car. The load is well cleated and braced in the center, so that there is seldom any shifting or breakage in transit. The carload shipments are sent to

Butte, Helena, and Billings, Mont., and to various points in North Dakota and South Dakota, such as Fargo, Grand Forks, and Aberdeen, as far east as Lincoln, Nebr., and Minneapolis, Minn., and to such Canadian points as Winnipeg, Calgary, Edmonton, Regina, and Moosejaw.

Nearly all of the berries in the valley are marketed through the association, there being very few growers who are not members. All of the berries that are not shipped are turned in to the cannery, the association paying a uniform price to its members, determined after the running expenses and the selling prices are known. During the season of 1912 a considerable quantity of the fruit turned in to the cannery was put up in barrels. Practically no berries are evaporated in this section.



FIG. 15.—Inspecting red raspberries on the platform at Puyallup, Wash., before loading them into a refrigerator car,

CAUSES OF DECAY OF FRUIT IN TRANSIT.

The most common cause of decay of berries in transit and after arrival on the market are mold fungi, principally gray or black mold (*Botrytis*) and blue mold (*Penicillium*). Neither of these two fungi seriously attacks firm, sound berries, but they quickly attack and cause the decay of berries injured or bruised in handling or soft from being overripe. Investigations with less tender and perishable fruits, such as oranges, apples, pineapples, lemons, and the like, have demonstrated that there is a direct relationship existing between the type of handling given the fruit and its behavior after picking, in transit, and after arrival on the market. The results of the work with berries are fully consistent with the general principles under-

lying the relationship between methods of preparing the fruits for shipment and their behavior in transit and on the market. The methods of handling red raspberries in picking and in shipping determine the condition of the berries on the market fully as much as does handling in the shipment of oranges.¹ In the handling of red raspberries three factors primarily determine the amount of decay and the condition of the berries on the market: (1) Injuries in handling; (2) sorting as to ripeness; (3) promptness and rapidity of cooling.



FIG. 16.—A pony refrigerator used for the shipment of small lots of red raspberries under refrigeration. The open refrigerator shows six compartments, three of which are filled.

INJURIES IN HANDLING.

The most common injuries result from carelessness in picking the berries from the vines, by breaking or bruising them when pulling them away from the receptacle and by mashing them in the hand before placing them in the cups. In inspections on the market it is a very common thing to find cups containing masses of decay

¹ Stubenrauch, A. V., Ramsey, H. J., and others. Factors governing the successful shipment of oranges from Florida. U. S. Department of Agriculture Bulletin No. 63, 50 p., 1914.

Powell, G. Harold, and others. The decay of oranges while in transit from California. Bureau of Plant Industry Bulletin No. 123, 79 p., 1908.

easily traceable to berries mashed in the hand of the picker before being placed in the cup. Serious injury and decay also result from attempts by pickers to sort over filled or partly filled cups.

The injury and decay that result from breaking the berry or bruising it when pulling it away from the receptacle is probably the most common and serious. This injury can be avoided almost entirely by using three fingers instead of two and by pulling the berries off straight rather than sidewise.

Three fingers distribute the pressure more evenly and greatly lessen liability from injury, provided no more pressure is applied than is necessary to separate the berries from the receptacle.

SORTING AS TO OVERRIPENESS.

One of the most common causes of decay and deterioration is carelessness in sorting berries into their proper grades at the time of picking. Berries intended for long-distance shipment must be at as nearly the same stage of development as possible, with none overripe or soft at the time of picking. Every grower knows when a berry is in ideal condition for long-distance shipment and strives to have his pickers exercise due precaution and care to place only sound, uninjured, unbroken, properly matured berries in the cups. This practically means the removal of the berries from the vines as quickly as they will slip off the core. Overripe and soft berries when mixed with the properly handled and properly matured ones cause the spoilage of the whole cup and reduce the value of the whole crate. A soft berry will soon break down; molds will gain entrance and not only cause the decay of the single berry but spread throughout the cup. Too much emphasis can not be placed on faultless sorting.

PROMPTNESS AND QUICKNESS IN COOLING.

Apparently the ripening processes of red raspberries continue very actively after the fruit is removed from the vine, and especially if the temperatures are relatively high. To arrest the physiological activities which constitute ripening, to retard and prevent the germination of mold spores, and to retard the development and growth of mold fungi, it is essential that the berries be promptly and quickly cooled after picking. The picked berries lose much of their life by standing in the sun after picking and by delay in getting them into a refrigerator car. The necessity of prompt and quick cooling will be more fully discussed later.

OTHER INJURIES.

Considerable injury also occurs in hauling over rough roads or on springless wagons and in rough, careless handling to and from the wagon in such a way that the berries roll around in the cups,

becoming injured, mashed, and broken. The same applies to handling in the car or in pony refrigerators. A pony refrigerator (fig. 16), when being loaded into an express car, is often tilted at such an angle and so violently jolted that berries are badly mashed and injured by rolling around in the cups. Much greater care could easily be exercised even in such a hurry-up job as loading express shipments. Rough, uneven loading platforms are also the cause of considerable injury as the fruit is trucked to the car.

FREQUENCY OF PICKING.

It is customary to pick a patch over once a day, although patches are frequently left two or three days. The pickings should be made sufficiently close together to avoid having any considerable proportion of overripe berries. Overripe berries are usually sent to the cannery, but a lot of such berries in a patch makes it extremely difficult to obtain good and proper sorting, the result being that a great many good shipping berries with a few overripe ones in them are sent to the cannery or else are shipped, with the inevitable decay and poor returns as a result.

RELATION OF RAINFALL TO HANDLING.

The climatic conditions during a season to a great extent determine not only the shipping quality but also the quantity shipped in a fresh state. During wet, rainy periods it is impracticable to pick berries. Much fruit becomes overripe, and if the rainy weather continues for any length of time all the berries will lack the desired firmness, being soft, very tender, and full of moisture. The rains therefore determine largely the fresh-fruit output and are a big factor in the success attained during any one season. Many berries mold on the vines during muggy weather, and all the berries are so extremely tender as to stand practically no pressure or handling without injury.

RELATION OF METHODS OF GROWING TO KEEPING QUALITY.

The liability to injury in handling depends to some extent also on the methods of growing and training. The visible evidence in the valley seems to indicate that potash used with judgment tends toward firmer and better keeping berries. This statement is not based on any experimental evidence, but only on a general existing belief among the better growers and on observation during the two seasons covered by this work. It is, of course, unnecessary to consider all those factors in culture that tend to produce first-class fruit. The desirability and advantage of high quality are unquestioned. Much

can be done in training to reduce the liability to injury, especially at harvest time. It is customary to cut out the greater portion of the nonbearing wood, leaving only sufficient to allow for a good selection of canes for next year. The remaining nonbearing canes are oftentimes sorted out from the others and tied to a separate wire in order to facilitate picking. This enables the pickers to get at the berries more easily, lessens the liability of leaving berries that should be picked, and makes it possible to do the picking with more care.

THE LABOR PROBLEM.

The fact that much of the picking is done by help which has had no previous experience necessitates a great deal of painstaking work on the part of the grower and foreman in instructing the pickers in proper methods and in seeing that they follow instructions. Until the labor becomes thoroughly trained the picking may be anything but that desired or necessary for the best results. A great many of the pickers are children, and it is almost impossible to impress upon them the reason or necessity for careful handling and to imbue them with the proper feeling of responsibility. Aside from other considerations, the fact that the pickers are paid almost entirely on the basis of quantity makes the problem of securing proper care in handling even more difficult.

HANDLING, AN ECONOMIC PROBLEM.

The problem of handling is one of great economic importance and equally as momentous as that of growing. The fullest measure of success can come only to those who, after producing the finest fruit possible, successfully solve the problem of handling so as to insure the maximum carrying quality of the fruit. To overcome the losses in transit and to broaden the marketing territory are strictly business propositions related to methods of organizing the berry business, to systems of hiring labor, to methods of picking, hauling, and shipping, to methods of inspection at receiving sheds, and to the proper utilization of precooling and refrigeration. Any system of handling that puts a premium on quantity and not quality must necessarily be detrimental to the best interests of the industry.

CAREFUL-HANDLING EXPERIMENTS.

During the season of 1911 and 1912 a series of careful-handling experiments was made in order to determine the relation of the methods of handling to the decay and deterioration of red raspberries in transit and after arrival on the market. Each lot or series consisted of a number of carefully handled crates of raspberries with the same number of comparable commercially handled crates from the same yard and picked at the same time. During the season of

1911 it was found impracticable to make shipments, and therefore all lots were held in a fully iced refrigerator car, from which fruit was withdrawn after lapses of time representing transit periods of four, six, and eight days, respectively. The percentages of decay were determined by carefully separating the moldy and soft berries from the sound ones, the percentages being based on actual weights of moldy, soft, and sound berries.

RESULTS OF THE HOLDING TESTS IN 1911.

The carefully handled berries held in a car for four days developed only 0.4 per cent of decay, while the commercially handled comparable lots developed an average of 4.6 per cent of decay. The berries held six days in a car developed even more striking differences, the

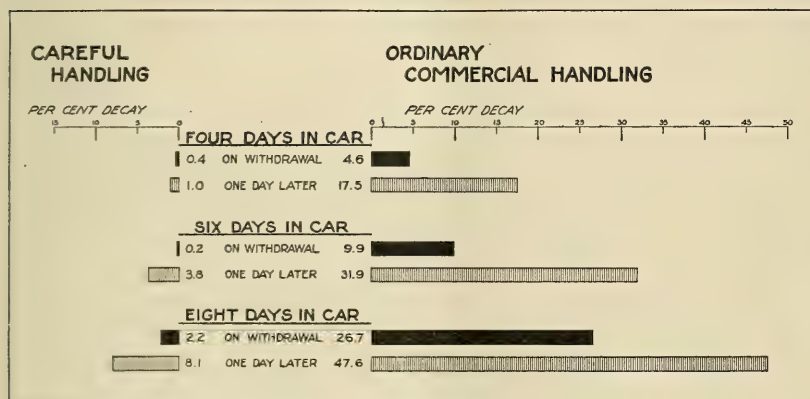


FIG. 17.—Diagram illustrating the percentage of decay in carefully handled and commercially handled red raspberries held in an iced car at Puyallup, Wash., for four, six, and eight days, on withdrawal and one day later, season of 1911.

carefully handled 0.2 per cent and the commercially handled 9.9 per cent of decay. At the end of eight days the carefully handled fruit had developed but 2.2 per cent of decay as against 26.7 in that commercially handled, or only one-twelfth as much. At the end of eight days the carefully handled fruit had developed only half as much decay as that commercially handled in the car but four days. Figure 17 and Table I show the differences in decay due to differences in handling methods. Included under the term "decay" as used here are both soft and moldy berries. Under the first designation are included berries entirely too soft and mushy to be marketable for any purpose, but showing no mold.

The development of less decay in the fruit held in the car six days than in that held for but four days is an apparent inconsistency, but it is easily accounted for when one takes into consideration the fact that different lots of fruit must necessarily be used at each inspection.

While the aggregate of fruit used in these investigations was large, the quantity of fruit inspected each time for any part of a single experiment or test was necessarily limited, and such slight discrepancies as occur in Table I and others usually result from occasional bad decay in a single cup or crate.

TABLE I.—*Decay in carefully handled and commercially handled red raspberries held in an iced car at Puyallup, Wash., in 1911.*

Time in iced car.	Decay on withdrawal.		Decay 1 day after withdrawal.	
	Carefully handled.	Commercially handled.	Carefully handled.	Commercially handled.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
4 days.....	0.4	4.6	1.0	17.5
6 days.....	.2	9.9	3.8	31.9
8 days.....	2.2	26.7	8.1	47.6

MARKET-HOLDING TESTS.

One-half of the fruit from each withdrawal was held one day under ordinary market conditions and another determination of decay and deterioration was made. The result of these inspections is even more striking than of those made on withdrawal. This is self-evident when allowance is made for the extremely favorable conditions existing for the development of mold or deterioration when fruit is exposed to contact with warm air. Imperfections or injuries due to improper and rough handling, as well as overripe berries, offer the maximum conditions for spoilage. The carefully handled fruit held four days in the refrigerator car and one day after withdrawal developed 1 per cent of decay, the commercially handled 17.5 per cent. The after-withdrawal inspections of the 6-day lot showed 3.8 per cent of decay in the carefully handled and 31.8 per cent of decay in the commercially handled fruit, while similar inspections of the 8-day lots showed 8.1 per cent of decay in the carefully handled and 47.6 per cent in the commercially handled berries. Figure 17 brings out most strikingly these differences and the relation of handling to keeping quality.

From this showing it is safe to assume that fruit handled with the proper degree of care can be shipped fully twice the present distance, or a distance representing a haul of 4,000 miles, as against a 2,000-mile haul for ordinarily handled fruit. This assumption is further strengthened and the results in 1911 further corroborated by the results of the careful-handling work during the season of 1912, when a series of actual shipments was made to Grand Forks, N. Dak. The fruit held in the iced car at Puyallup the previous season was really under more favorable conditions than exist in a fully loaded refrigerator car, as the holding car was only partially filled and the rate

of cooling of all lots was more rapid than in fully loaded cars. It was therefore deemed necessary to obtain some data from actual shipping experiments.

Great difficulty was experienced in procuring the desired number of cars consigned to any one market, but arrangements were made to place the experimental crates in cars destined for Grand Forks or routed through that point, opening the cars and withdrawing the crates in transit. The crates were transferred to an iced car held there, the transfer being made quickly after wrapping in thick canvas to protect the contents from contact with the warmer air and prevent a consequent condensation of moisture. The fruit was transferred to the refrigerator car and held for different lengths of time after arrival there, in order that conditions representing hauls of approximately four, six, and eight days might be obtained. The period of transportation to Grand Forks was usually a little less than four days,

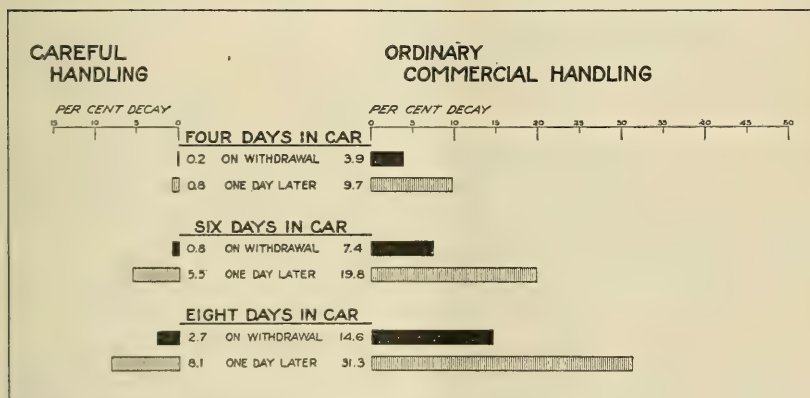


FIG. 18.—Diagram illustrating the percentage of decay in carefully handled and ordinary commercially handled red raspberries after arrival at Grand Forks, N. Dak. The decay shown under the heading "Four days in car" is that developed in transit from Puyallup to Grand Forks, and the decay shown under the headings "Six days in car" and "Eight days in car," respectively, represent additional holding periods in an iced car at Grand Forks of two and four days, making total transit periods of six and eight days.

and the fruit was quite thoroughly cooled in transit, so that the transfer to another iced car resulted in but slight change in temperature. The holding periods of two and four days in this car after arrival therefore gave conditions during transit periods of six and eight days. These periods correspond with the holding periods at Puyallup during the season of 1911.

SHIPPING TESTS DURING THE SEASON OF 1912.

Figure 18 and Table II show the results of these inspections and corroborate fully the results of the season of 1911.

The carefully handled fruit shows but 0.2, 0.8, and 2.7 per cent of decay at the end of four, six, and eight days, respectively, as against

3.9, 7.4, and 14.6 per cent of decay for the commercially handled berries for the same periods. The after-withdrawal inspections are equally striking. There was less decay (2.7 per cent) in the carefully handled fruit at the end of eight days than in that commercially handled at the end of but four days (3.9 per cent). These results so fully corroborate those obtained during the season of 1911 that further discussion is unnecessary.

TABLE II.—*Decay in carefully handled and commercially handled red raspberries shipped to Grand Forks, N. Dak., in 1912.*

Time in iced car.	Decay on withdrawal.		Decay 1 day after withdrawal.	
	Carefully handled.	Commercially handled.	Carefully handled.	Commercially handled.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
4 days.....	0.2	3.9	0.8	9.7
6 days.....	.8	7.4	5.5	19.8
8 days.....	2.7	14.6	8.1	31.3

WHAT CONSTITUTES CAREFUL HANDLING.

In view of the superior carrying qualities of the carefully handled fruit and the marked advantage that its better market-holding properties give it, it may well be asked, What constitutes careful handling? This can best be answered by a description of the methods used in picking the specially and carefully handled lots.

Special care was taken to remove the berries from the bushes without breaking or crushing them and to place each berry in a cup immediately, in order to avoid mashing it in the hand. Bruising in picking can be avoided to a great extent by using three fingers on each berry instead of two. When only two fingers are used, the pressure is concentrated at two points on the berry, while the use of three fingers distributes the pressure more evenly and very greatly lessens the liability to injury, provided no more pressure than is necessary is used to separate the cap from the receptacle. Great care was exercised to place all overripe berries in separate cups and to put none but sound, unbroken, uninjured, and properly matured berries into cups and crates intended for long-distance shipment. Berries may be considered properly matured as soon as they will slip off the core without breaking. The frequency of picking also is a factor in careful handling. Proper handling, as above described, is comparatively a simple matter where the pickings are made sufficiently close together to avoid having an undue proportion of overripe berries in the yard. If a grower gets behind in the picking, careful handling is much more difficult of accomplishment, owing to the great quantity of "overripes." The filled crates were hauled to the receiving station or car in spring wagons and covered

with canvas to protect the fruit from the sun and dust. Previous to loading, the crates containing the fruit were kept in the shade of a receiving shed and exposed as little as possible to the sun after removal from the vines. When loading on and unloading from the wagons and when placing in the car the crates were handled with all possible care, especial effort being made to keep them in a horizontal position and to prevent hard jolting in placing them on the platform or in the car. The too frequent practice of tipping crates nearly on end in loading cars results in considerable bruising, as the berries roll from side to side in the cups and against the division board and the cover.

That the berries can be handled commercially with sufficient care to insure the desired keeping quality is not seriously questioned by intelligent growers. It is largely a matter of the thorough organization of their

forces, proper instruction in methods of handling, constant supervision, and careful inspection of work. That many growers are already accomplishing the work as well or better even than did the workers of the Bureau of Plant Industry is indicated in Table III and figure 19, which show the percentages of mold, soft berries, and total deterioration in the first inspection of fruit from twelve different growers. The decay runs all the way from 1.3 per cent to 39 per cent.

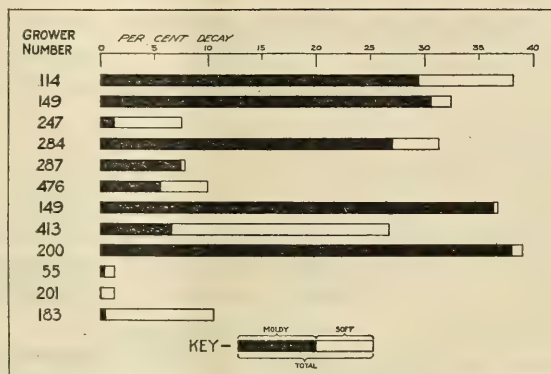


FIG. 19.—Diagram illustrating the percentages of moldy and of soft fruit and total decay in commercially handled fruit obtained from various growers, this fruit being held in an ordinary iced car for four days at Puyallup, Wash., in the season of 1911.

TABLE III.—Moldy and soft berries and total decay in commercially handled lots of red raspberries from different growers held in an iced car at Puyallup, Wash., in 1911.

Grower No.	Moldy.	Soft.	Total decay.	Grower No.	Moldy.	Soft.	Total decay.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
114.....	29.5	9.0	38.5	149.....	36.4	0.4	36.8
149.....	30.6	1.8	32.4	413.....	6.7	20.0	26.7
247.....	1.3	6.2	7.5	200.....	38.0	1.0	39.0
284.....	27.1	4.2	31.3	55.....	.4	.9	1.3
287.....	7.4	.4	7.8	201.....	.1	1.2	1.3
476.....	5.6	4.3	9.9	183.....	.5	10.0	10.5

These men paid their pickers the same wage. The great differences noted were due mainly to the character of the work required by the owner from his help. These figures emphasize most strongly the need of closer supervision of the picking by the association. If all the handling operations could be brought up to the standard of the better ones shown in the above table, the carrying quality and reputation of the fruit would be greatly enhanced, the markets could be greatly extended, and more remunerative prices could be obtained.

EFFECT OF DELAY IN COOLING ON KEEPING QUALITY.

Nearly everyone recognizes the need for the prompt cooling of fruits intended either for shipment or storage, particularly such tender fruits as red raspberries, which ripen very rapidly after removal from

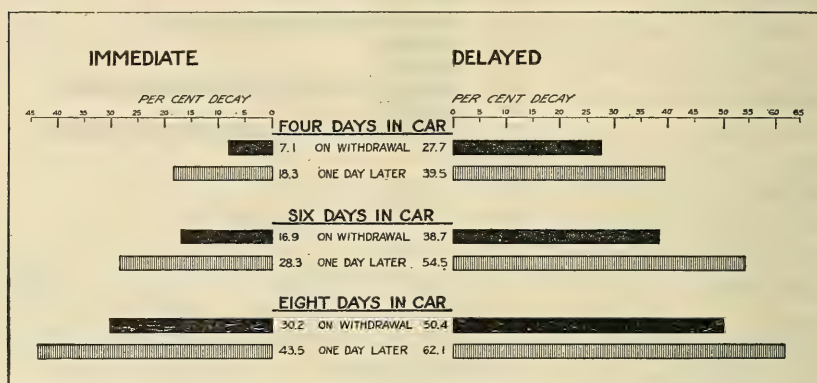


FIG. 20.—Diagram illustrating the percentage of decay in red raspberries of immediate and delayed loading, season of 1911, representing comparable lots of fruit, the immediate loaded as soon as brought in from the field, the delayed held over until the next day before being placed in the refrigerator car. Both lots were held in an iced car at Puyallup, Wash.

the vines, especially if the temperatures are relatively high. To demonstrate the effect of delay in cooling on red raspberries, a certain number of crates from each series during the 1911 season were held out and not placed in the refrigerator car until the afternoon of the following day. Table IV and figure 20 bring out strikingly the results.

TABLE IV.—Decay in commercially handled red raspberries following immediate and delayed loading at Puyallup, Wash., in 1911.

Time in iced car.	Decay on withdrawal.		Decay 1 day after withdrawal.	
	Immediate.	Delayed.	Immediate.	Delayed.
4 days.....	7.1	27.7	18.3	39.5
6 days.....	16.9	38.7	28.3	54.5
8 days.....	30.2	50.4	43.5	62.1

A comparison of the figures and diagrams should be sufficient. The immediate lots showed 7.1 per cent of decay as against 27.7 per cent of decay in the delayed lots of the same fruit after four days in the car. At the second inspection, after six days in the car, the immediate lots had 16.9 per cent of decay as against 38.7 per cent of decay for the delayed berries, and at the end of the 8-day period the immediate lots showed 30.2 per cent of decay as against 50.4 per cent of decay in the delayed fruit. The inspections one day later are equally striking and convincing. These results serve to emphasize further the importance of protecting the fruit after picking from undue exposure to the sun and of getting the fruit under refrigeration quickly.

PRECOOLING EXPERIMENTS.

In the precooling experiments with red raspberries at Puyallup during the season of 1911, it was not possible to combine the careful-handling investigations with precooling. The precooling tests included, therefore, only commercially handled lots. The precooling was accomplished by means of the portable ammonia plant of the Department of Agriculture, both before and after loading the fruit in the cars. For the warehouse precooling tests—cooling before loading—a refrigerator car was used as a warehouse cooling room by putting in a false floor and ceiling and the fruit loaded into the car was cooled by forcing the cold air from the precooling plant under and through the false floor and the fruit. After cooling, the fruit was transferred into another pre-iced refrigerator car for shipment, the loading being done through a canvas hood to protect the fruit from contact with the warm outside air. Only a few tests were made with this outfit.

Most of the precooling tests were made with fully loaded cars, the cold air being forced in one bunker through the fruit and taken out at the other bunker and back to the plant for recooling. It was not practicable to obtain inspections at the market end, and therefore marked crates from the precooled cars, together with check crates of the same fruit nonprecooled, were held in an iced car for four, six, and eight days. In most cases the average temperatures of the fruit in the precooled cars were reduced to about 40°, the initial temperatures being often above 70° F.

The results of this work, while decidedly beneficial in most respects, emphasize strikingly, as in the case of many other fruits used in similar tests, that precooling can never be depended upon to accomplish nearly as much as careful handling. While precooling proved decidedly beneficial, it did not in any measure overcome the bad effects of rough, careless, and improper handling. The most

noticeable feature of the precooling was the improved appearance of the precooled berries, which were decidedly brighter and fresher than those held without precooling.

PRECOOLING EXPERIMENTS IN THE SEASON OF 1911.

The inspections were made in the same way as those previously described for the careful-handling investigations. Table V and figure 21 give the results of the precooling work during the season of 1911.

TABLE V.—*Decay in commercially handled red raspberries that were immediately loaded and held in an iced car with and without precooling.*

Time in iced car.	Decay on withdrawal.		Decay 1 day after withdrawal.	
	Precooled.	Non-precooled.	Precooled.	Non-precooled.
	Per cent.	Per cent.	Per cent.	Per cent.
4 days.....	2.2	5.9	9.5	16.5
6 days.....	9.1	15.4	19.1	34.8
8 days.....	17.2	27.3	36.0	45.1

Precooled, immediately loaded, commercially handled berries showed 2.2 per cent of decay and the nonprecooled 5.9 per cent of de-

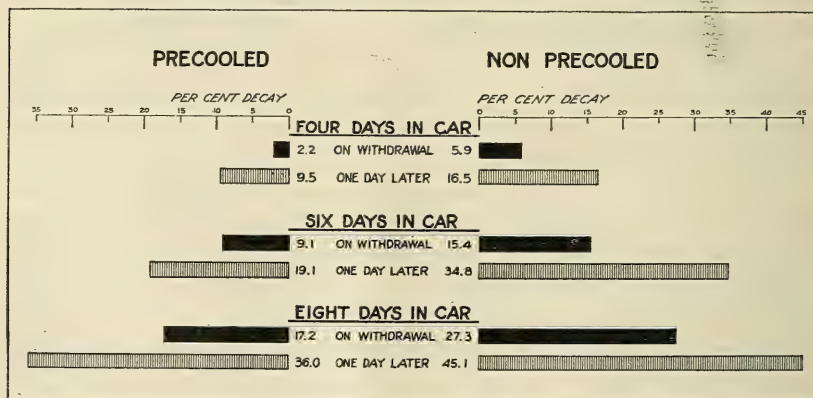


FIG. 21.—Diagram illustrating the percentage of decay in comparable precooled and nonprecooled commercially handled red raspberries held in an iced car, season of 1911, at Puyallup, Wash., for four, six, and eight days.

cay at the end of the 4-day period, and 9.1 per cent of decay and 15.4 per cent of decay, respectively, at the end of the 8-day period. The after-withdrawal inspections are consistent with the withdrawal results. The ratio of percentages of decay is much the same at the

end of the 4-day period (9.5 per cent of decay in the precooled and 16.5 per cent of decay in the regular iced) and at the end of the 8-day period (36 per cent of decay in the precooled and 45.1 per cent of decay in the nonprecooled). These data, while emphasizing the beneficial effects of precooling, bring out most strongly the importance of careful handling.

PRECOOLING EXPERIMENTS IN THE SEASON OF 1912.

During the season of 1912 the precooling investigations were continued, and carefully handled as well as commercially handled berries were used. The fruit was shipped to Grand Forks, N. Dak., as in the case of the handling investigations previously noted. Un-

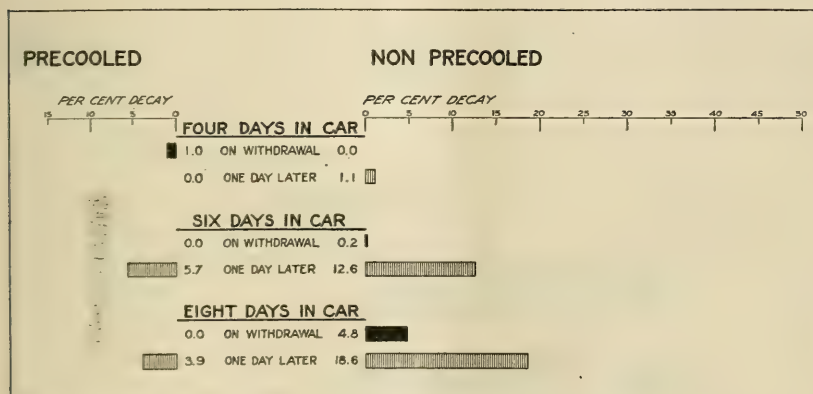


FIG. 22.—Diagram illustrating the percentage of decay in precooled and nonprecooled carefully handled red raspberries shipped from Puyallup, Wash., to Grand Forks, N. Dak., season of 1912.

fortunately, owing to market conditions a number of precooled and check cars were diverted and did not reach the inspection point. The data, while therefore not as comprehensive as desirable, are nevertheless consistent with the results of the 1911 season and are considered sufficiently conclusive to warrant final deductions being made.

As in the season of 1911, more beneficial results were obtained from careful handling than from precooling alone. The results, however, bring out clearly the fact that precooling with proper handling is of great service and value in the preservation of fruits like red raspberries in maximum good condition while in transit. Table VI and figure 22 show the results of the carefully handled precooled and nonprecooled shipments.

TABLE VI.—*Decay in carefully handled red raspberries shipped to Grand Forks, N. Dak., under ordinary icing, with and without precooling, in 1912.*

Time in iced car.	Decay on withdrawal.		Decay 1 day after withdrawal.	
	Precooled.	Nonprecooled.	Precooled.	Nonprecooled.
	Per cent.	Per cent.	Per cent.	Per cent.
4 days.....	1.0	0	0	1.1
6 days.....	0	.2	5.7	12.6
8 days.....	0	4.8	3.9	18.6

The precooled, carefully handled berries showed practically no decay on withdrawal after four, six, and eight days in the car, except 1 per cent after four days. This is an apparent discrepancy, but it is easily accounted for when one considers that it is impossible to use the same lots for inspection more than once. The nonprecooled berries showed no decay at the first withdrawal, 0.2 per cent of decay at the second, and 4.8 per cent of decay at the end of

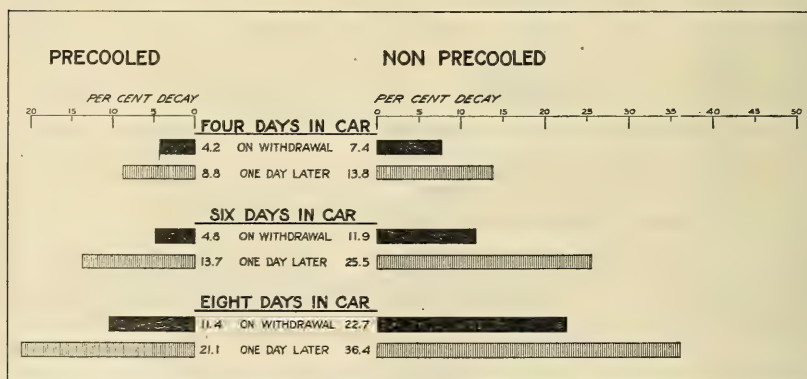


FIG. 23.—Diagram illustrating the percentage of decay in precooled and nonprecooled commercially handled red raspberries shipped from Puyallup, Wash., to Grand Forks, N. Dak., season of 1912.

the 8-day period. The after-withdrawal inspections, after the fruit had been held on the market for one day, are even more striking and instructive. The first market-holding inspection of the precooled fruit showed it to be apparently sound, while at the second inspection there had developed 12.6 per cent of decay and at the third inspection there was found 18.6 per cent of decay. While there was little difference between the precooled and nonprecooled fruit at the withdrawal inspections, there was quite a marked difference in favor of the precooled berries in the market-holding inspections. The nonprecooled fruit apparently was somewhat riper, having ripened or matured more rapidly under the higher temperatures in the cars

not precooled, and it therefore commenced to break down sooner than the precooled fruit.

The effect of precooling on commercially handled fruit is equally consistent with the results of the season of 1911, as shown in Table VII and figure 23. It is hardly necessary to discuss these data in detail.

TABLE VII.—*Decay in commercially handled red raspberries shipped to Grand Forks, N. Dak., under ordinary icing, with and without precooling, in 1912.*

Time in iced car.	Decay on withdrawal.		Decay 1 day after withdrawal.	
	Precooled.	Nonprecooled.	Precooled.	Nonprecooled.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
4 days.....	4.2	7.4	8.3	13.8
6 days.....	4.8	11.9	13.7	25.5
8 days.....	11.4	22.7	21.1	36.4

While again emphasizing the beneficial effects of precooling, these results emphasize even more strongly the importance of careful handling. The difference in decay between the precooled and nonprecooled berries indicates clearly the effect of temperature on the acceleration or retardation of the ripening processes and the growth of mold fungi. The more promptly the fruit is cooled and the lower the temperature (without actual freezing) at which the fruit is held in transit, the more quickly and completely are the ripening processes checked and the slower is the growth of mold fungi.

TABLE VIII.—*Decay in carefully handled precooled and commercially handled nonprecooled red raspberries shipped to Grand Forks, N. Dak., in 1912.*

Time in iced car.	Decay on withdrawal.		Decay 2 days after withdrawal.	
	Carefully handled precooled.	Commercially handled nonprecooled.	Carefully handled precooled.	Commercially handled nonprecooled.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
4 days.....	1.0	7.4	0	13.8
6 days.....	0	11.9	5.7	25.5
8 days.....	0	22.7	3.9	36.4

Table VIII and figure 24 give a comparison of decay in cars of precooled, carefully handled fruit and nonprecooled, commercially handled fruit, which can not fail to be impressive. Careful handling with precooling made possible an 8-day trip with sound delivery and practically no spoilage during the market-holding period, while the commercially handled fruit nonprecooled showed 7.4 and 22.7 per

cent of decay, respectively, at the end of 4 and 8 day transit periods, with 13.8 per cent of decay and 36.4 per cent of decay at the respective market-holding inspections.

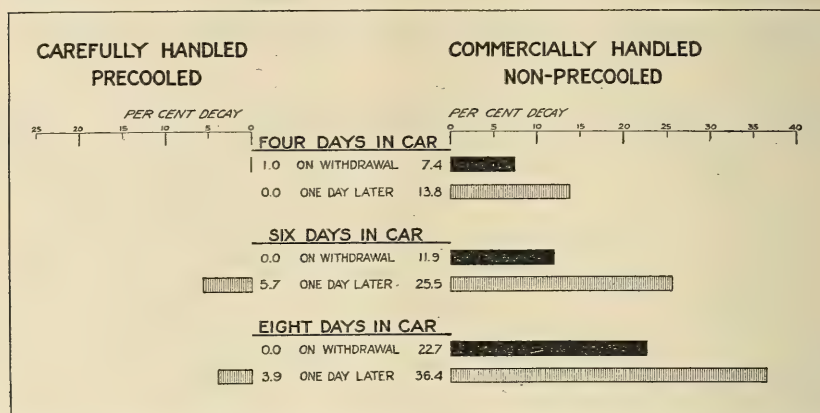


FIG. 24.—Diagram illustrating the percentage of decay in carefully handled precooled red raspberries in comparison with commercially handled nonprecooled red raspberries shipped from Puyallup, Wash., to Grand Forks, N. Dak., season of 1912.

DECAY IN TOP AND BOTTOM CRATES.

The temperature effect is again strikingly emphasized in a comparison of decay in the top and bottom crates in a refrigerator car. It has been conclusively demonstrated that there is a marked differ-

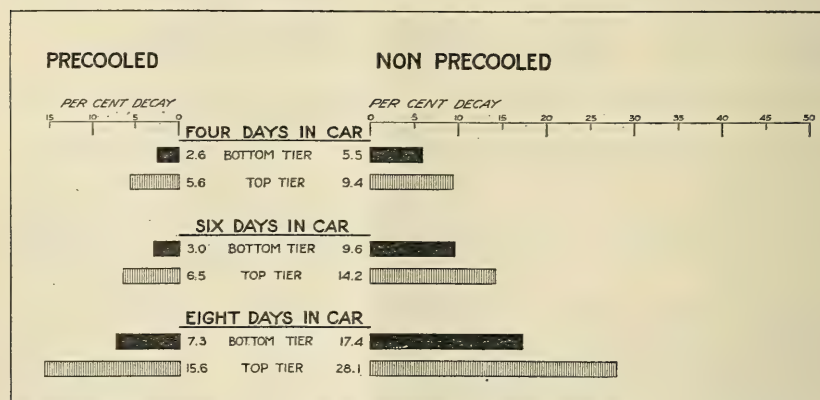


FIG. 25.—Diagram illustrating the percentage of decay on withdrawal in bottom and top tiers in precooled and nonprecooled commercially handled red raspberries shipped from Puyallup, Wash., to Grand Forks, N. Dak., season of 1912.

ence in temperature at the bottom and the top of the load in an iced car. This difference is usually more than 10 degrees and less than 20 degrees. In the nonprecooled lots the bottom crates showed 5.5 per cent of decay and the top crates of the same fruit 9.4 per cent of decay at the end of four days. A study of Table IX and figure 25

shows these differences to be consistent for all inspections. The pre-cooled cars show similar differences, the bottom having 2.6 per cent of decay and the top 5.6 per cent at the first withdrawal inspection.

TABLE IX.—*Decay in the top and bottom tiers in commercially handled red raspberries shipped to Grand Forks, N. Dak., under ordinary icing, with and without precooling, in 1912.*

Time in iced car.	Decay, precooled.				Decay, nonprecooled.			
	On withdrawal.		1 day after withdrawal.		On withdrawal.		1 day after withdrawal.	
	Top.	Bottom.	Top.	Bottom.	Top.	Bottom.	Top.	Bottom.
4 days.....	<i>Per cent.</i> 5.6	<i>Per cent.</i> 2.6	<i>Per cent.</i> 10.4	<i>Per cent.</i> 7.3	<i>Per cent.</i> 9.4	<i>Per cent.</i> 5.5	<i>Per cent.</i> 18.9	<i>Per cent.</i> 8.7
6 days.....	6.5	3.0	16.1	11.1	14.2	9.6	30.5	20.5
8 days.....	15.6	7.3	24.9	17.1	28.1	17.4	44.0	28.7

TEMPERATURE CONDITIONS IN AN ICED REFRIGERATOR CAR.

Temperature readings taken during the season of 1913 in a car of blackberries in transit from Puyallup to Grand Forks show clearly the reason for the marked differences in decay in berries in the top and bottom tiers. Figure 26 illustrates this range of temperatures. The upper curve shows the temperature of the fruit in the top tier, temperature readings being taken at the following points: Next to the bunker, halfway from the bunker to the door, and in the middle of the car. The temperatures in

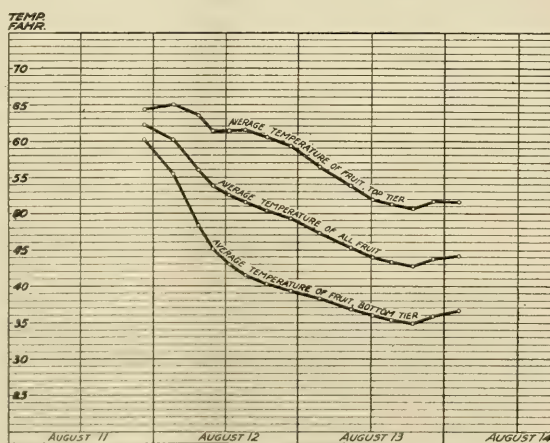


FIG. 26.—Diagram illustrating the average temperature of fruit in top and bottom tiers and average temperature of all fruit in the car of blackberries in transit from Puyallup, Wash., to Grand Forks, N. Dak., season of 1913.

the lower curve were taken in the bottom tier in the same relative positions in the car and were the average of readings taken at three points, the same as in the upper curve. The middle curve is simply an average of the top and bottom tier readings. In some cases the difference in average temperature between the top and bottom crates was more than 20 degrees, enough to account for the difference in

decay in the fruit in the top and bottom tiers. The lesser difference at the beginning of the trip is partly accounted for by the fact that the car was partially precooled before shipment. The data presented in these curves emphasize strongly the necessity of loading the car in such a way as to afford the freest possible circulation of cold air from the bunkers to all portions of the car.

It is not uncommon where salt has been added at each re-icing en route to find spoilage both from freezing and from deterioration on account of too high temperatures. In such cases the temperature at the floor next to the iced bunkers becomes sufficiently low to cause the freezing of some of the fruit on the floor in the ends of the car, while at the top in the middle of the car the temperature is often so high that the fruit is in an overripe condition. The temperature tests made in fully loaded cars of berries in transit would indicate that it is not ordinarily advisable to add salt in re-icing after the first 40 hours in transit. During the first part of the journey and before shipment no doubt the addition of a certain percentage of salt to the crushed ice in the bunker greatly aids in obtaining quick cooling, but the addition of salt at each re-icing during a journey of over 40 hours may result in considerable damage by freezing in certain portions of the car. If there was some way of circulating the cold air throughout the car so as to prevent the formation of cold pockets, salting throughout at every re-icing would doubtless be highly beneficial. Possibly the use of slats or racks on the floor would facilitate the free circulation of cold air sufficiently to avoid the danger of freezing, even though salting was practiced throughout en route.

THE APPLICATION OF PRECOOLING.

As a result of these investigations, every effort has been made by the industry to procure proper handling, and a precooling plant has been erected for cooling the fruit after loading it into the cars. After observing the methods of operating a number of precooling plants, one is impressed with the need of organizing or adjusting the fruit picking and delivery so as to allow sufficient time to precool the fruit successfully before it enters upon its journey to a distant market. The most serious and common fault is that of allowing too little time for precooling; that is, attempting to do precooling in less than half or quarter of the time actually necessary to accomplish the desired results. Our experience has demonstrated beyond question that the effective precooling of berries can not successfully be accomplished in less than four or five hours. The precooling of a car, fully loaded, for an hour or two hours accomplishes little in the way of actual temperature reduction or in results from the standpoint of the condition of the fruit on arrival. The investigations of

the Department of Agriculture, as above reported, have demonstrated clearly the beneficial results of precooling red raspberries, but to get full value out of the money expended in precooling it is absolutely necessary to do it properly and well.

Precooling can not be depended on to offset the bad effects of careless, rough handling, and for such purpose is not justified any more than is a half job of precooling of either properly or improperly handled berries. Thorough precooling of properly handled red raspberries is fully justified by the results, and is of the greatest assistance in delivering berries to the market in good condition. Any association, organization, or individual wishing to utilize precooling in connection with the long-distance shipment of berries should adapt the picking and handling operations to the needs of the situation, so as to permit sufficient time for thorough precooling. Otherwise, the money put into precooling is very largely wasted.

SUMMARY.

The results of these investigations demonstrate that the care exercised in handling and the promptness with which the fruit is cooled are among the most important factors determining the distance over which red raspberries can be successfully shipped. These two factors, more than any other, determine the condition of the berries on arrival at the market and the area of successful distribution. In connection with the handling and shipping of fresh red raspberries the following recommendations are made.

While methods of growing, pruning, and training have primarily in view the production of the largest possible crop at the most profitable period during the season, the grower should also keep in mind the ease or difficulty of harvesting. If the methods of growing, pruning, and training are such as to facilitate picking, there will be less liability to injury in handling. Too close planting or the non-separation of bearing from nonbearing canes increases the difficulty of doing the picking either thoroughly or properly.

Before the harvesting season commences all surplus new growth should be cut out and the remaining new canes separated from the bearing vines in such a way as to facilitate picking, both as regards the finding of the fruit and the picking of it with the least amount of injury.

In picking, three fingers should be used to remove the berry from the receptacle instead of two, as is the common practice. Three fingers distribute the pressure and lessen the liability to injury.

Each berry should be placed in a cup as soon as removed from the vine, in order to avoid mashing. When several berries are held in the hand while picking it is difficult to avoid crushing them.

Crushing or bruising from any cause is to be avoided, as it is often the cause of serious losses on the market.

The greatest care should be exercised in sorting to place only firm, good-shipping berries in shipping cups and all soft, overripe, injured berries in canning cups. The inclusion of one overripe berry in a cup may spoil the whole cup, one cup a whole crate, and a few such crates a whole carload.

It is very important that the yards be picked over so frequently that an undue proportion of berries will not become overripe. The frequent picking over of a patch makes good sorting in picking much easier of accomplishment. The 6-basket carrier used in picking should be kept in the shade, and as soon as the cups are filled or the picking completed the berries should be taken to the sorting shed.

No sorting over of berries in any individual cup should be attempted or permitted, owing to injuries resulting from rehandling. Sorting or grading at the shed must necessarily be confined to grading by cups, cups showing overripe or mashed berries to be placed in canning crates or in crates for local shipment only. Cups containing only sound, firm berries should be placed in shipping crates.

The berries should be hauled to the receiving station on wagons provided with good springs and they should be covered to protect them from both dust and the sun.

In handling to and from the wagon and to the car the utmost care consistent with commercial requirements and conditions should be exercised to keep the crates in a horizontal position. Tipping crates on end may result in much decay, as the berries are bruised in rolling around in the cups and oftentimes mashed against the cover.

The berries should be brought in as promptly as possible after picking and promptly placed in a refrigerator car or cooling room, if one is available. Delay, especially in warm weather, in handling the berries, either in the field or at the receiving station, may shorten the life of the fruit and is commonly the cause of serious losses.

Every precaution should be taken to have the cars iced 12 to 24 hours prior to loading and to keep the car doors open only when actually loading.

The cars should be so loaded as to allow the free circulation of air between the tiers of crates, in order to facilitate quick, effective cooling.

The crates themselves should be, as far as is consistent with the strength of the packages, the cost of manufacture, etc., partially slatted on the bottom and sides to permit free circulation of the air and quicker refrigeration.

Strips or racks on the floor would aid very materially in bringing about the quicker and more uniform cooling of the load. The circulation would be much freer and more rapid, lessening the temperature

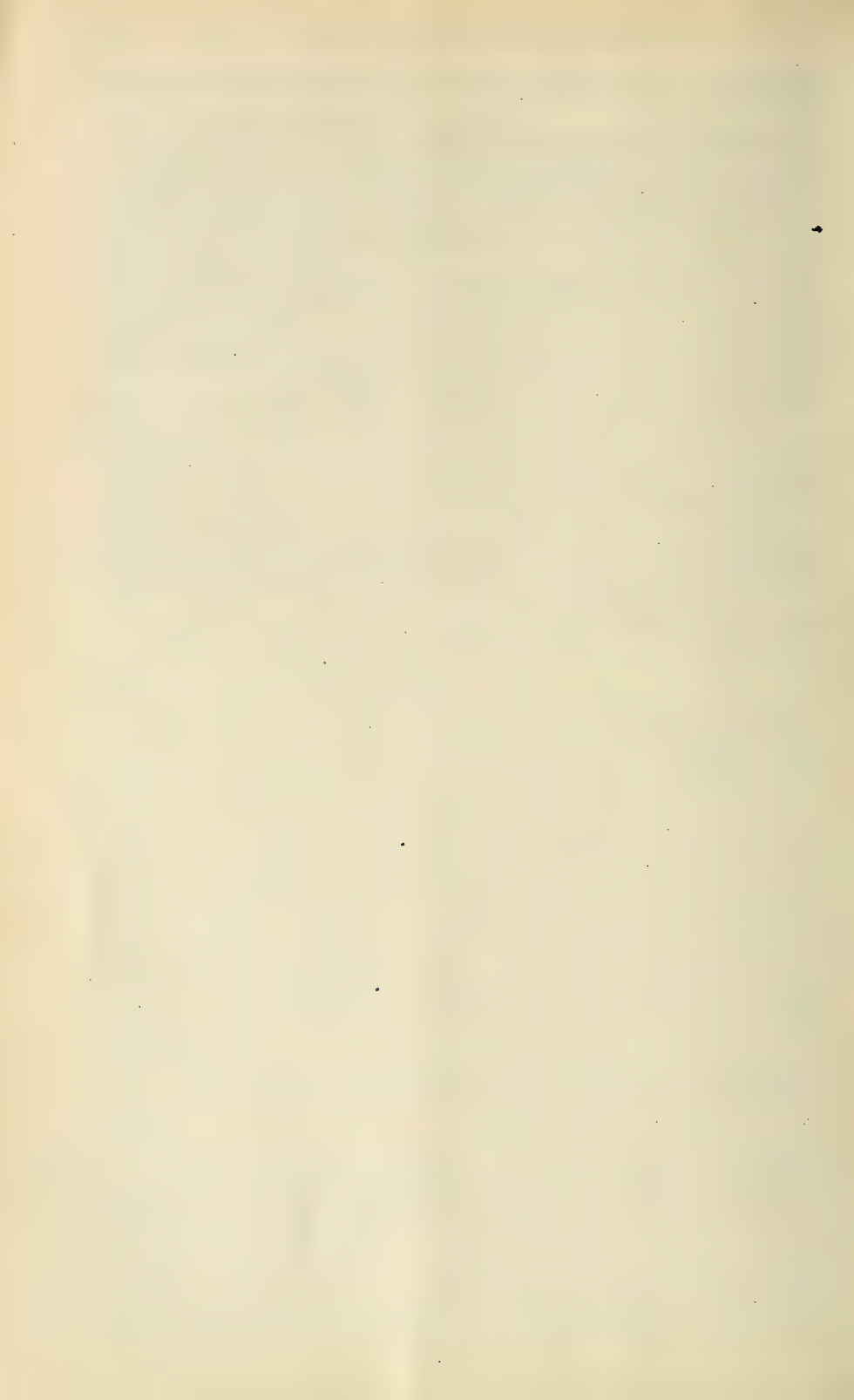
inequalities shown between the top and bottom tiers and various parts of the load.

The rather common practice of putting in from 100 to 200 pounds of salt at the first re-icing after loading and at each re-icing in transit is on the whole beneficial. If the salting of the ice, however, is continued beyond 40 hours, or thereabouts, it may result in serious damage by freezing the fruit in the bottom crates next to the bunkers.

Where the fruit has been precooled the addition of salt during the first two or three re-icings will no doubt be beneficial, but salt should be used more sparingly than where used with nonprecooled cars. If the raspberries are to be precooled, there should be the least possible delay between picking and precooling.

The precooling should be thorough, whether done before or after loading. Half or partial precooling is not justified. In order to do the precooling promptly and to allow sufficient time in which to do it thoroughly, the operations of picking, of hauling to the receiving station, of loading, of moving cars, and of precooling must be made to conform, as far as possible, to train schedules. Precooling can not be depended upon to counteract the bad effects of rough and careless handling methods.







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WM. A. TAYLOR, Chief



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PROFESSIONAL PAPER.

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FOREST PATHOLOGY IN FOREST REGULATION.

By E. P. MEINECKE,

Forest Pathologist, Office of Investigations in Forest Pathology.

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INTRODUCTION.

At the time of the creation of the national forests in the United States the Government very suddenly found itself confronted with the problem of organizing an enormous acreage of practically virgin timber. It was natural that American forestry turned to the experience of the Old World for guidance in this huge task; it was quite as natural that the present state of European forestry should have served as the ideal to be reached in the shortest time possible. In organizing the administrative machinery, European precedent could be followed more or less closely, but not so in almost all other phases of forestry. Except for certain economic factors and the development of modern machinery, conditions influencing the lumber industry in the United States are very dissimilar to those in the typical forest countries of central Europe. Our virgin forests them-

selves, and consequently the timber for sale, are more or less in the condition of European forests of several hundred years ago. The administration found itself then in the position of a man forced to take over not only an obsolete factory producing at random articles of daily necessity in enormous quantities without having any control whatever over the quality turned out, but also a huge stock of products of all kinds and all values. Modern sales methods alone can not make the product any better, and the sudden adoption of modern methods of efficiency in the manufacturing end of the business would soon disorganize the entire factory.

It is clear that in the most important branch of forestry, silviculture, the blind adoption of European methods must encounter serious difficulties. Perhaps we are too prone to look upon European forestry as a science worked out in all its details, the results of which are universally accepted as definitely settled. Critical perusal of modern European forestry literature shows an entirely different state of affairs. Even in Germany many of the fundamental problems of forest organization are steadily discussed and are far from being considered as settled. Furthermore, what Gaskill¹ said 11 years ago is true to-day, namely, that "European foresters have not developed a true system or science of silviculture capable of being applied to virgin conditions or to all conditions."

The lessons taught us by earlier forest history in Europe, the adaptation rather than adoption of European principles to American conditions, and the development of new principles to suit our own special needs are therefore the means by which forestry in the United States will finally solve the silvicultural problems before it at the present day.

REGULATION OF YIELD.

WORKING PLANS.

One fundamental problem has occupied the administration of the national forests ever since their creation, that of working plans as the expression of forest organization leading to sustained yield.

Any speculation with regard to the adoption of a system of regulation must necessarily refer to the normal stand, whether this is clearly understood and stated or not. Now, there is no such thing as the 100 per cent normal stand. Consciously or subconsciously the normal stand is taken as the ideal, and from this allowances are made according to the degree in which the stand deviates from the normal. It is a remarkable fact that even in European forestry no working system has developed of expressing with accuracy the value of allowances to be made. This is partly due to the fact that the managed European forests are relatively closer to the normal. Frequent thinnings and improvement fellings eliminate most of the undesirable indi-

¹ Gaskill, Alfred. Silviculture applied to virgin forest conditions. *In* Proc. Soc. Amer. Forest., v. 1, no. 2, pp. 62-69, 1905. (See p. 67.)

viduals from the stand, which is kept as fully stocked as possible. The problem is further simplified by the prevalence of pure stands or of stands composed of two, rarely more, well-matched species. The management of even-aged stands or stands of all ages also permits a relatively close approximation to the normal.

All these factors are comparatively rare in our practically virgin forests, which are about as far from the normal as possible. As forests they are with few exceptions rather 100 per cent abnormal, and this applies equally well to all unmanaged practically and genuinely virgin forests of the world. The farther the forests are removed from the normal the less can European results from relatively normal stands be applied, and particularly if the abnormality is complicated by the presence of a greater number of commercial species on the same stand, as is so often the case in our forests. It is not to be expected that at the very beginning of its career the Forest Service should have possessed all the facts upon which to base a rational system of sustained yield. Intensive work of decades is necessary to secure even the very foundations.

It is clear that this lack of fundamental facts must be reflected in any attempt to establish some system of sustained yield and, therefore, in any policy of regulation of cut. While Kirkland¹ emphatically demands a policy of cutting national-forest timber on the Pacific coast on the basis of a sustained annual yield, Greeley,² on the other hand, points to the difficulties confronting the establishment of a sustained annual yield in the forests of the United States. In his opinion even, "modern conditions governing the distribution and sale of lumber make the sustained yield from the standpoint of a permanent supply for consumers of wood very much of a fiction." We have at the present time no more authoritative statement concerning the policy of the administration of the national forests.

With regard to the regulation of sustained yield, Chapman³ arrives at a similar result in discussing the regulation of cut on national forests.

Until recently the annual cut permitted upon national forests has been determined by Von Mantel's method, based solely on the present nature of the merchantable stand and a somewhat arbitrary rotation. A few attempts have been made lately to base the cut upon the increment of the forest by use of the Austrian formula. At the same time there has come a general awakening to the fact that our knowledge of the actual increment of virgin forests is conspicuously lacking. Without this knowledge systematic regulation of yield must remain on crude and wholly unsatisfactory foundations. The question can not be dodged by quoting the generality that in virgin forests growth equals decay.

¹ Kirkland, B. P. The need of a vigorous policy of encouraging cutting on the national forests of the Pacific coast. *In* *Forestry Quart.*, v. 9, no. 3, pp. 375-390, 1911.

² Greeley, W. B. National forest sales on the Pacific coast. *In* *Proc. Soc. Amer. Forest.*, v. 7, no. 1, pp. 42-50, 1912.

³ Chapman, H. H. Coordination of growth studies, reconnaissance and regulation of yield on national forests. *In* *Proc. Soc. Amer. Forest.*, v. 8, no. 3, pp. 317-326, 1913.

This "generality," in which almost every word is open to criticism, seems to have become one of the stand-bys of American forestry. It finds its chief support in the assumption that our forests to-day, having been untouched by man and exposed to the same factors of their surroundings since times immemorial, must represent more or less exactly the same character they had 100 or 1,000 years ago. But we have practically no genuinely virgin forests; in the great majority of commercial accessible stands—and here we are interested only in these—man has for centuries practiced some kind of primitive forestry by setting fires. This "Piute forestry" has changed the aspect of many stands so completely that the term "virgin forests" is far from being correctly applied. At best, can one speak of scattered virgin stands here and there. Even in the latter the assumption that the present stand has more or less the same character as 100 to 1,000 years ago reposes upon another assumption, namely, that here the ecological formation has reached the final stage of development and has come to stay. Of the remaining part of the cited rule of thumb all factors are more or less unknown.

Our knowledge of increment is, according to Chapman, "conspicuously lacking."¹ We know just as little about actual extent and progress of decay in virgin forests, so that the "generality" is reduced to an equation in which all factors are unknown. Besides, the term "decay" leaves out all losses from the decrease in number of trees steadily going on in the forest, as in every community of living beings. Prompted, perhaps, by a subconscious realization of this fact, the term "decay" in the equation is sometimes supplanted by "deterioration." This makes matters even worse. Deterioration in this connection often means the visible loss irrespective of cause. It is primarily a numerical consideration. A number of trees containing certain amounts of timber annually drop out through various causes, and this loss is then said to offset the annual increment. Secondarily, it might include loss from decay. In forest regulation it is not the number of trees and the volume of timber they produce per acre that count, but the volume of sound, merchantable timber that we can expect to raise; and the only factor in the equation of any value would be, therefore, not decay only and deterioration or numerical loss of individual trees but "total loss." The components of this total-loss factor are known. They include the dropping out of individual trees by death from suppression or "old age," fire, snowbreak, lightning, windfall, insects, diseases of vital parts of the tree, and finally loss through decay. What we do not know are the respective values to substitute for these components in the actual figuring of total loss.

¹ More recently Barrington Moore has published a valuable study—Yield in uneven-aged stands—in *Proc. Soc. Amer. Forest.*, v. 9, no. 2, pp. 216-228, 1914.

The same laxity noted in the use of the terms "decay" and "deterioration" is commonly found in the use of the term "decadence," as applied to a stand or a given species, which is often understood to include individual decadence from old age; that is, arrested or minimized growth, liability to attack from fungi and insects, and finally decay. The fact that a given species is unusually liable to heart rot does not make it decadent. Many of our most thrifty and aggressive species are particularly subject to heart rot. It is also doubtful whether this hypothetical knowledge, if ever attained, of the total rate of total loss in "virgin" forests, as compared with the equally hypothetical rate of increment of the forests as a whole, would help us to any extent. The vastness of our forests in area creates a tendency either to think in broadest terms and to overlook the fact that a forest is an artificial unit made up of natural units, the stands with all their immense variety of character, or, on the other side, to take a familiar unit and to transfer its characteristics to the whole. The latter mistake is more easily remedied than the first. As a science, forestry must be founded upon inductive methods. Intensive study of detail alone can form a solid basis for the formulation of principles.

What is needed is exact studies of all components of the total-loss factor per species before we attempt to fix the total-loss factor for the stand.

Such detailed studies will be easiest in all-aged pure stands of a thrifty species little liable to decay. Unfortunately the vast majority of stands on national forests in the West are composed of two to five or more species of very different characters. It may be that the total annual loss equals the annual increment in some of the medium long-lived species of the pine group least liable to decay. It can not be true for the extraordinarily long-lived redwood and big tree, with their unusual resistance to decay, insects, and storms. It is equally untrue for all shorter lived species much exposed to decay and other influences that make for loss. *Libocedrus decurrens*, for example, although most aggressive and thrifty, is from an early age on liable in an uncommon degree to the attacks of *Polyporus amarus*, which renders as much as 70 or 80 per cent and even higher percentages of the stand completely unmerchantable. Merchantable incense cedar is of high value; so much the greater, then, is the total-loss factor. The same is, *mutatis mutandis*, true for white fir and a number of other species. For all these the increment is not only offset but far exceeded by the decay of the valuable heartwood; the total annual loss is far greater than the annual increment, although numerically the loss may not be apparent.

The gain through increment, we must remember, consists of sapwood of little value; the loss by decay, on the other side, affects the

valuable heartwood. Neither is there any constant accumulation of gain; after some years the sapwood is turned into heartwood and as such becomes liable to decay. In other words, in trees of this group infected with heartwood-destroying fungi, the value of newly formed wood is small; when it becomes valuable by transformation into heartwood it becomes subject to decay—that is, loss. This loss from decay is by its very nature as a heart rot confined to those individuals in which heart-rot formation has taken place. All trees below the age of heartwood formation do not enter into consideration. In speaking of a given stand the representation by ages must be of prime importance. In all considerations of regulation it is necessary, therefore, to make a clear distinction between forests and stands, between many-aged and even-aged stands, between mixed and pure stands, with particular emphasis on the composition of the stand as to species. All generalization is not only useless but misleading.

But in full realization of the almost complete lack of fundamental knowledge, American forestry is confronted with the urgent necessity of adopting, even temporarily, some kind of a system of regulation of yield. Whatever this system may be, its tentative, temporary, and local character can not be overemphasized.

Various attempts at adopting local temporary systems have found an expression in the shape of working plans. Inseparable from the problem of working plans is the choice of a rational rotation and cutting cycle.

ROTATION.

The gleanings in American literature treating on the choice of rotation from a general point of view are rather meager, outside of a few well-known handbooks, such as those by Recknagel,¹ by Fernow,² and by Roth,³ particularly in so far as the practical application to our virgin forests is concerned. Recknagel⁴ excludes financial rotation from North American forests with the following words:

Since this method of calculating the rotation [financial rotation or that of highest soil rent] is suitable only to very intensive conditions, it would serve no useful purpose to elaborate it at this point.

On the other hand, the strong influence of European forestry is clearly felt in the ever-recurring advice to adopt some kind of a financial rotation in the national forests of the United States. Kirkland⁵ is of the opinion that—

¹ Recknagel, A. B. *The Theory and Practice of Working Plans (Forest Organization)*, 235 pp. New York, 1913.

² Fernow, B. E. *Economics of Forestry*, 520 pp. New York, 1902.

³ Roth, Filibert. *Forest Regulation, or the Preparation and Development of Forest Working Plans*, 218 pp., illus. (maps). Ann Arbor, Mich., 1914. (*His Michigan Manual of Forestry*, v. 1.)

⁴ Recknagel, A. B. *Op. cit.*, p. 39.

⁵ Kirkland, B. P. Working plans for national forests of the Pacific Northwest. *In Proc. Soc. Amer. Forest.*, v. 6, no. 1, pp. 16-37, 1911. (See p. 21.)

A rotation based on the financial rotation, possibly modified somewhat towards the rotation of the highest income, is no less adapted to Government forestry than to private forestry.

Greenamyre¹ advocates a financial rotation in the composite type of the Apache National Forest, the "rotation of greatest volume production being out of question." In his specific recommendations for western yellow pine, Douglas fir, and blue spruce, however, rotation of greatest volume plays a far greater rôle than financial rotation. Such important factors in financial rotation as soil capital, quality increment, and rent are neglected or only hinted at. Value increment and depreciation enter into his calculations in a general way only, evidently from a lack of exact figures.

Barrington Moore² expresses himself strongly against the adoption of a financial rotation.

It would be out of place in this paper to enter into a discussion of the possibility at the present time of fixing a rotation of greatest income or a financial rotation more deeply than to point to the immense difficulties encountered as soon as we try to substitute actual values for the factors entering into their computation derived from experience in our own country. We lack at the present time the very fundamentals on which to base the determination of highest forest rent or highest soil rent.

The Forest Service has, in full realization of the uncertainty of almost all factors which would or should enter into a financial rotation formula, adopted, for the present at least, a tentative silvicultural rotation of maximum-volume production.

The factors entering into the determination of silvicultural rotation or of greatest volume being more easily accessible, it is quite natural that American forestry should show a tendency toward its application, as shown in a number of published and unpublished working plans.

Attempts at fixing some kind of a rotation age are found in several publications. Woolsey³ tentatively proposes a rotation of 200 years for yellow pine without giving a basis for the choice of any particular system of rotation.

Barrington Moore⁴ says that on the Plumas National Forest "the rotation should theoretically be that of maximum-volume production. The use of a financial rotation by the Government, in a region

¹ Greenamyre, H. H. The composite type on the Apache National Forest. U. S. Dept. Agr., Forest Serv. Bul. 125, 32 pp., 4 figs., 1913. (See p. 30.)

² Moore, Barrington. The essentials in working plans for national forests. *In* Proc. Soc. Amer. Forest., v. 6, no. 2, pp. 117-128, 1911. (See p. 126.)

³ Woolsey, T. S. Western yellow pine in Arizona and New Mexico. U. S. Dept. Agr., Forest Serv. Bul. 101, 64 pp., 11 figs., 4 pls., 1911. (See p. 51.)

⁴ Moore, Barrington. Chapman's method of studying yield, p. 93, 1913. To accompany forest plan, Plumas National Forest, district 5. Appendix (continued), Silviculture. (Unpublished. Furnished by courtesy of the U. S. Forest Service.)

capable of producing large saw timber, can not be justified. * * * It would probably be better to fix the rotation at the period during which the *rate* of volume production is greatest or shortly after it, provided this is long enough to give the most valuable product."

Munger¹ comes somewhat closer to a consideration of the financial factors for a rotation of Douglas fir in pure even-aged stands in the Pacific Northwest.

From the quotations given, one fact stands out clearly: We are still groping more or less in the dark where choice of rotation is concerned, and we are even lacking the fundamentals upon which to base the principles to govern us in making a proper choice. It also appears that in many cases the term "actual felling age" should be substituted for rotation. Rotation in itself signifies return or succession in a series. Fernow² has warned, as early as 1905, against mixing up "actual felling age, the time when a stand is actually cut or to be cut, and normal felling age (rotation), the time when in a scheme of continued management it is proposed to have it cut again and again—a mere standard time. Few stands are cut in the age of the rotation determined for the forest as a whole." Where a "rotation" of yellow pine, for instance, of 200 years is advocated, it is evident that this can not be meant to constitute the fixed period at which yellow pine should be cut again and again in the future. It is really the actual felling age, the time when a given stand of yellow pine is actually to be cut in the future, not a succession of 200-year periods. The rotation itself will be much shorter, as European experience has shown us. Moreover, it is more than doubtful whether our successors in 200 to 400 years will pay much attention to the rules we may try to lay down for so remote a future.

CUTTING CYCLE.

The impossibility of predicting with even a modest degree of probability what will happen in the future and of anticipating changes in conditions of an economic nature is responsible for the vagueness with which the question of fixing definite cutting cycles is treated. Tentatively, cutting cycles of about 50 years have repeatedly been advocated for uneven-aged stands (mixed and pure) under the selection method, as a policy to be followed on virgin national forests. If present economic conditions should prevail in the next 50 years—that is, if the demand for timber should continue to fall far short of the actual annual increment—it would hardly pay a lumbering concern of the future to extend its operations to cut-over areas before 50 to 60 years had elapsed. Even then it seems doubtful whether the

¹ Munger, T. T. The growth and management of Douglas fir in the Pacific northwest. U.S. Dept. Agr., Forest Serv. Circ. 175, 27 pp., 4 figs., 1911.

² Fernow, B. E. Forest terminology. In *Forestry Quart.*, v. 3, no. 3, pp. 255-268, 1905. (See p. 264.)

amount of timber contained in the few overholders left as seed trees and in individuals at or just below the diameter limit established in a first cutting would prove attractive to purchasers of the future, provided always no change in the lumber market should take place. The diameter limit now fixed on many national forests may be said to be about 12 inches, varying somewhat with the species and local conditions. Few trees below this diameter will reach such dimensions in 50 years as to form a merchantable stand, judged by our standards of to-day.

If it is unwise blindly to take over principles and policies developed and more or less accepted in countries with old-established and far-advanced forestry and apply them to the first stages in the organization of our virgin forests, the study of the history of the forestry movement and development in other countries can not but be of the greatest practical value. We are justified also in assuming that the history of forestry will repeat itself and that forestry in all countries with large virgin or practically virgin forests in touch with the general market will run through the same phases of development as it did during the last centuries in central Europe, but at a very much faster pace, owing to the enormously enhanced facilities of transportation and marketing and the rapidly increasing demand for timber.

If this be true, a cutting cycle of about 50 years may prove too long. To judge from the development of timber values in Europe, our once cut-over stands should prove attractive in a shorter period.

In determining the duration of cutting cycles, it is reasoned that the accessible virgin timber in the national forests should be cut once before operations return to the first areas logged over. How much time this first culling may consume we have no means of telling. It should be remembered, however, that the system naturally presenting itself is that of selection cutting, and although there is a decided tendency toward heavier marking approaching clean cutting, this latter should be taken *cum grano salis*. Actually, the reproduction left includes all individuals up to and sometimes beyond 12 inches diameter breast high; that is, trees that have reached a considerable age and that in 50 years will have grown to what would be classed in European forestry as veterans.

CUMULATIVE RISK.

In fixing long-term cutting cycles, a most important point has not been sufficiently emphasized, namely, the "cumulative risk" from fire, windfall, frost, and so-called deterioration to which a given stand is exposed during so long a period. The longer the cycle the greater the ratio of risk. The unparalleled development of fire protection in the national forests of the United States, it is true, promises fairly to exclude actual destruction from fire on any large scale; but, as long as

there will be fires from unpreventable sources (lightning), the risk in extended cutting cycles increases from year to year with the growth in value of the stand. The shorter the period in which a merchantable stand can be produced and turned into cash the smaller will be the risk of loss.

Loss from windfall is inevitable in many localities as a direct consequence of selection cutting. It is clear that the cumulative risk of a longer cycle is far in excess of a shorter one. Evidently, devastating windstorms are more likely to occur during a period of 50 years than during a shorter one. Moreover, the loss in cash value, even in single trees, from windfall is bound to be heavier in the older stands. The larger, bulkier, and therefore the more valuable the tree, if sound, the more it is exposed to windfall. Falling trees in brushing against their standing neighbors not infrequently cause more or less serious wounds by bruising or tearing off the bark.

The greatest risk, however, involved in the long cutting period is from "deterioration," so called.

In nature a steady process of elimination goes on. Of thousands of seedlings springing up together in dense growths, comparatively few reach sapling size, very few grow into poles, and fewer, even, to standards. This natural thinning through competition in the fight for soil, food, and light is furthered by various dangers to which the young plants are exposed, such as from certain insects, foliage and twig diseases, injury from mammals, snowbreak, frost, and drought. Later, the surviving members of the stand are confronted with dangers from the same and other sources, such as suppression, lightning, insects, frost, and decay. The elimination of the weaker members effects a selection of older, well-established individuals, some of which may still suffer from the competition of their thriftier neighbors, but are not forced out of the community, or, to use Fernow's¹ well-chosen terminology, trees which are "oppressed," not suppressed. As long as improvement cutting on a larger scale on the national forests is impossible, the percentage of oppressed trees will depend upon the length of the cutting cycle. Both these oppressed trees and their more favored companions are exposed to dangers from which their earlier life was free.

Frost does a good deal of damage; here we are less interested in the damage done to the foliage or to the bark than in those more or less long cracks in the wood which are caused by very low temperatures. In cold weather the wood cylinder shrinks more in a tangential than in a radial direction. Particularly at sudden low temperatures, when the volume of the outer layers decreases rather suddenly while the inner layers are still free from frost and have

¹ Fernow, B. E. Forest terminology. *In* Forestry Quart., v. 3, no. 3, pp. 255-268, 1905. (See p. 266.)

shrunk but little, differences in internal tension will cause the outer layers to split vertically. With rising temperature the frost crack closes. Not always is the bark able to stretch sufficiently over a frost crack. Often the bark tears open, and if low temperature occurs again and again, the cracks will not be able to heal over and will remain open for many years, giving the air access to the heartwood and incidentally allowing spores of wood-destroying fungi to germinate and infect it. Even if no infection takes place, these frost cracks very seriously impair the value of the timber. The older and bulkier the tree the greater is the danger of frost-crack formation. The risk naturally increases with the length of the cutting cycle. Infection, of course, can take place only through open frost cracks; internal frost cracks, besides impairing the value of the timber, can not be without influence on the chemistry and physics of the wood.

Although lightning occasionally strikes the smaller trees, even poles and saplings, it is to be expected in the nature of things that taller trees will be more exposed to injury from this cause. Very little is known, so far, as to the actual damage done by lightning in our forests. Destruction of individual trees has been frequently reported, and Plummer¹ gives a series of illustrations of injury to forest trees from lightning. He treats, however, only of those very gross cases in which even the least educated eye will recognize the cause of the injury.

We know through Robert Hartig's² classical investigations, which were continued by Von Tubeuf, that destructive lightning is rare in comparison to the overwhelmingly greater number of cases of lighter injury from lightning, varying from more or less large wounds visible on the outside of the tree to the small and insignificant local killing of parts of the cambium and of the living bark which can only be detected by careful dissecting.

The symptoms of lightning injury in our forest trees are easily recognized from Hartig's excellent descriptions. They are particularly common and conspicuous in white fir.

For practical purposes, we have to consider here only those forms of lightning injury which in some way endanger the life, the health, or the commercial value of the tree; this will include not only actually destructive cases, but also very large numbers of lesser injuries. The accumulation of risk during a long-time cutting cycle becomes self-evident, particularly in view of the fact that the danger from lightning increases quite out of proportion to the increase in height of the tree and the development of the root system.

¹ Plummer, F. G. Lightning in relation to forest fires. U. S. Dept. Agr., Forest Serv. Bul. 111, 39 pp., 16 figs., 1912.

² Hartig, Robert. Untersuchungen über Blitzschläge in Waldbäumen. In *Forstl. Naturw. Ztschr.*, Jahrg. 6, 1897, Heft 3, pp. 97-120; Heft 4, pp. 145-165; Heft 5, pp. 193-206, 83 figs.

Hartig, Robert. Neue Beobachtungen über Blitzbeschädigung der Bäume. In *Centrl. Gesam. Forstw.*, Jahrg. 25, 1899, Heft 8-9, pp. 360-331, figs. 47-71; Heft 12, pp. 523-544, figs. 81-110.

Although young trees are also exposed to the attack of insects, it is clear that a colony of bark beetles will prove far more injurious in killing a merchantable tree than in killing a small pole. Moreover, certain insects seem to have a predilection for larger sizes. The probabilities of attack increase with the length of the cutting cycle. Besides, the older the tree and the more it has been exposed to wounding the more liable does it become to attack by wood-boring insects which materially reduce the value of the timber.

The timber contained in trees killed by lightning, as long as they are not destroyed, and in those killed by bark beetles may be utilized, and, with increasing timber values, will be utilized before they deteriorate.

The few veterans which have withstood the many dangers of earlier life do not go on living forever; they finally succumb like the rest.

It is still an open question whether forest trees are theoretically immortal and die only through the devastating influence of severe storms, lightning, insects, certain diseases caused by fungi, such as *Armillaria mellea* and *Fomes annosus*, or because the root system of the veteran finally has exhausted all available resources of the soil within its reach. As we are interested here only in the future of cut-over areas in relation to the length of the cutting cycle, it is unnecessary to enter into a discussion of this question. The cutting cycle for any one species will in all probability never be long enough to raise individual decadence from old age to the rank of an influencing factor. We should bear in mind, however, that individual decadence is not in itself deterioration unless decay sets in.

The importance of the reduction in the timber value of the tree through the agency of fungi, on the other side, can not be overemphasized. This reduction in timber affects either the prospective timber values—that is, the increment—or the present stock, or both. In the first case, the fungi in question (mostly Pyrenomycetes and rust fungi) inhabit living tissues of the foliage or of the young bark. The continuous drain on the assimilates of the foliage either in the leaves proper or on their way down through the bark is evidenced by a decrease in increment of the tree, which in long cutting cycles will represent a very considerable loss in timber values. In other words, trees affected with foliage or bark diseases will be far from yielding the timber we might expect from sound trees. It must be mentioned that losses in prospective values are not alone due to fungi; mistletoes and leaf-inhabiting insects are responsible for enormous deficits in yield. The economic rôle of the fungi, mistletoes, and leaf-inhabiting insects in our virgin forests is highly important and will remain so for a long time, on account of the difficulties connected with their control and even more on account of our very limited knowledge concerning their life histories and specific action. More intensive studies

on the members of this group must be left to the future. At the present time we are more interested in the preservation of our actual timber, including such values as will be formed in the near future.

Actual timber values are seriously endangered by wood-destroying fungi, all of which belong to the Hymenomycetes. With the exception of a very few (*Armillaria mellea*, *Fomes annosus*), which in attacking living roots first cut down the increment of their host and then invade the wood of the bole, they all inhabit the heartwood and generally leave the sapwood intact. As the principal timber values are stored in the heartwood, the enormous damage they are able to cause is all the more in evidence. All of these fungi are adapted to given hosts or groups of hosts; these groups are seldom very large. *Polyporus amarus*, for example, the cause of the extremely destructive heart rot of *Libocedrus decurrens*, can not grow, as far as is known, in any other host species. *Trametes pini*, on the other hand, attacks a number of pines, Douglas fir, and other conifers. The composition of the stand, as well as the representation of species, is therefore an important factor in the ecology of these fungi. Only those fungous spores which land on trees of the species to which they are adapted have a chance after germination to enter into the tree.

Being strictly heartwood inhabiting, these fungi, with the exceptions mentioned above, can, of course, only attack trees which already have formed heartwood. But as they are unable to penetrate the bark, they are harmless unless their spores are carried on to some wound or opening (branch stubs) in the protective skin represented by the bark. The longer the host is exposed to wounding, the greater will be the chances for infection.

As might be expected, therefore, the losses from decay in standing living trees are enormous in virgin forests. Even in the best managed forests of Germany losses from decay are heavy. Möller,¹ in figuring the damage done by *Trametes pini* in the pine forests of the Prussian Government, arrives at the astounding figure of more than 1 million marks (about \$250,000) annual loss from this source alone. In the period from 1905 to 1908 the Prussian Government spent \$87,480 in the control of *Trametes pini* in its pine forests.² In 1914 this sum had increased to about \$120,000.³

In American literature no reliable figures are available relating to the annual loss from decay in standing timber in virgin forests. Such figures can be obtained only by exact studies on representative areas, the methods of which the writer has been trying to work out

¹ Möller, A. Über die Notwendigkeit und Möglichkeit wirksamer Bekämpfung des Kiefernbaumschwammes *Trametes pini* (Thore) Fries. In *Ztschr. Forst- u. Jagdw.*, Jahrg. 36, 1904, Heft 11, pp. 677-715, pls. 4-5.

² Möller, A. Der Kampf gegen den Kiefernbaumschwamm. In *Ztschr. Forst- u. Jagdw.*, Jahrg. 42, 1910, Heft 3, p. 133.

³ Möller, A. Der Kampf gegen den Kiefern- und Fichtenbaumschwamm. In *Ztschr. Forst- u. Jagdw.*, Jahrg. 46, 1914, Heft 4, pp. 193-208.

during the last few years. In reason, all figures relating to loss in timber from decay, insects, lightning, etc., should apply only to such forested areas as are accessible at present or which will be in all probability accessible in the not too remote future. Inaccessible stands, whatever their protective value, do not represent timber values, and it is obviously wrong to include them in any estimate of the damage done to our timber stock on hand.

The rate of progress of decay in the individual tree is altogether unknown beyond vague guesses.

Hartig¹ has tried to figure the rate of growth of the mycelium, for instance, of *Fomes igniarius*. Möller² has made an attempt to figure the rate of growth of *Trametes pini* and resulting decay in *Pinus silvestris* from actual measurements in artificially infected trees. It is clear that unless such experiments are carried over a great many years, only the rate of growth of juvenile fungus plants starting from the infection can be measured, which can not be taken directly as a guide for figuring the growth of the older or mature fungus plants. Besides, the experiment is based upon the assumption that the fungus, after once having gained access to the interior of the tree, is independent of possible individual differences of its substratum, or, in other words, that the rate of growth is a fixed factor, irrespective of individual properties of the heartwood. This assumption has no solid basis. The rate of growth of the fungus plant, and therewith of decay, is undoubtedly one of the most inaccessible chapters of forest pathology, on account of the difficulty in finding a stable point of issue. There is at present no reliable method known of determining the actual extent of decay in the standing living tree. Indirect methods are the only means presenting themselves to-day; they leave much to be desired with regard to accuracy and can not be expected to yield results unless carried on over a long period.

What we do know is that decay in standing living timber from heartwood-destroying fungi causes very heavy losses and that decay is progressive. Sporophores develop on decaying trees, and the disease spreads through spores from one tree to other individuals of the same and sometimes of other species. Moreover, the decay starting from an incipient infection progresses in the heartwood of the individual tree until its most valuable lumber is destroyed. Decay being progressive, the cumulative risk from this source in long cutting cycles is therefore far greater than in the case of lightning or other injurious agents.

Unlike insects, heartwood-destroying fungi have few or no natural enemies; there is no such thing as "biological control" of decay.

¹ Hartig, Robert. Die Zersetzungserscheinungen des Holzes der Nadelholzbäume and der Eiche ... p. 116. Berlin, 1878.

² Möller, A. Der Kampf gegen den Kiefernbaumschwamm. In Ztschr. Forst- u. Jagdw., Jahrg. 42, 1910, Heft 3, pp. 129-146. (See p. 145.)

PERIOD OF TRANSITION.

American forestry stands now at the very beginning of a period of transition from the handling of virgin forests to actual forest regulation. The most urgent problem, therefore, consists in how to take care of our forests as we have them, with all their defects, with individual decadence and decay, and to leave them to future generations in as favorable a state as possible, judged by our very limited insight of to-day. At the present time the only means at the disposal of the Government to carry out any plans in forest regulation based upon what appears to us as sound silviculture is through timber sales. The Government does not and can not cut its own timber. It is therefore entirely dependent upon a highly variable outside factor with regard to the most important part of its silvicultural work, a factor over which it has but little control. All attempts at the regulation of yield must then be concentrated on timber-sales areas. A comparison between the area actually cut over annually and the total national-forest area that may eventually become accessible to logging operations will show the severe hardship under which the Government is forced to work. Moreover, timber sales do not always occur where they are most needed from a silvicultural point of view, nor do they always cover the entire natural units upon which it is desirable to prepare for a system of regulation. A comprehensive system of regulation on a larger scale following natural units is out of the question as long as the Government is not in a position to do silvicultural work on its own land where it is most needed.

The aim of the Forest Service at the present time consists less in how to do the greatest amount of good to future generations than in how to do the least harm and at the same time to do justice to our present-day conditions. Instead of exhausting our energies in sterile speculation of what might happen in 100 to 200 years from now, there is a strong tendency toward applying them first to the analysis of the most urgent needs of to-day and then to the exact and painstaking study of all the innumerable factors which enter into a comprehensive plan for the future structure of American forestry. It is well to remember that so far, not even the methods leading to the majority of such studies are worked out. The necessity of taking care of our present-day timber supply and of providing for the future in an extensive rather than intensive way has found strong expression in Chapman's¹ "American Method," where regulation is based not only on present volume and annual growth, but also on the "actual condition and amount of timber in the different age classes, with approximate knowledge of the behavior and condition of the age classes for an

¹ Chapman, H. H. Coordination of growth studies, reconnaissance and regulation of yield on national forests. In *Proc. Soc. Amer. Forest.*, v. 8, no. 3, 1913. pp. 317-326. (See p. 323.)

extensive future period." If "condition" is defined as state of health, not only as far as thriftiness of growth is concerned, but also with special regard to degree of merchantability as influenced by decay, the condition factor becomes a subject of pathological study.

Condition of the timber we hope to raise for the future, in the definition as given above, has a strong bearing on the possible regulation of yield. There can be no sense in figuring cutting cycles or rotation for future generations to follow unless we assume that our successors will find the area we have cut over covered with a stand not only apparently but really merchantable; in other words, with timber that is not rendered valueless by decay. The most ingenious speculation as to future yield is without any value whatever unless we have some way of figuring how long the steadily increasing but admittedly perishable timber stock can be left in the forest before it is liable to destruction by fungi.

The most important problem before us, therefore, is the determination in definite values of the condition of timber stock, present and future.

CONDITION OF TIMBER STOCK.

The condition of the timber as a factor in regulation may be expressed as the relation of the volume of timber destroyed or rendered unmerchantable by injurious agencies to the ideal volume of merchantable timber; or, in so far as forest regulation is interested not merely in the present but in the future, as the relation of the mean annual total loss to the mean annual increment.

It has already been pointed out that the concept of the relation of the mean annual total loss to the mean annual increment is without any value whatsoever as long as both factors are unknown. We are beginning to know in a small way something about the mean annual increment of certain species in certain types of some of the national forests. We are still completely ignorant as to the influence that the only silvicultural act of any importance open to the Forest Service, that is, cutting on timber-sales areas, will have on the increment of the remaining trees. This knowledge will come in due time. The value of the total-loss factor is altogether unknown. In order to attack this problem it is necessary to analyze it, to reduce it to its several components, and to study each in its turn. By synthesis the total loss can then be computed and the true relation to increment determined.

TOTAL LOSS.

The analysis of total loss already given shows that its components are known, but not their values. Of all these components the most important, the one that has the strongest bearing on the value of the stock of timber at hand, is loss from decay or heart rot caused by a group of heartwood-destroying fungi. Very young trees are not

susceptible to heart rot. No heart rot is possible before heartwood is formed. Unfortunately, we do not know anything about the formation of heartwood in our American species with relation to the age of the tree. The younger trees, while at present immune, will, in growing up and after formation of heartwood, become just as subject to heart rot as are their older companions. It is, then, of prime importance to know at what age living trees of a given species become particularly liable to attack from the one or more heartwood-destroying fungi that use their heartwood as a source of food. It is, further, of the utmost importance to know whether there are any conditions in the tree or outside of it that exert an influence over the development of the fungi once they have gained access to the heartwood of a tree to which they are adapted.

Beyond general statements to the effect that overmature trees do deteriorate from heart rots, very little information is to be gathered from American literature concerning the average age at which certain tree species become liable to attack from heartwood-destroying fungi. Greenamyre¹ mentions that in the Apache National Forest the decay in Douglas fir "no doubt largely offsets the growth" after the age of 210 years is reached.

Munger² gives a little more specific information:

The amount of decay found in living Douglas firs up to the time they are 150 years old or so is very small, but in mature and overripe timber there is a great deal of defect due to decay. . . . Douglas fir trees resist infection from fungi well until they become mature, when, because of the opening up of a stand, breakage, and scars due to the action of the elements and of fire and insects, and also because with advancing age their resistant power becomes less, they offer entrance to fungi.

It is not clear from the context whether Munger's figures are an estimate or are based on actual methodic investigation and measurements.

Findley Burns,³ in speaking of conditions on the Crater National Forest, gives the following information:

Many of the older Douglas firs are affected by a dry rot. . . . White fir is especially susceptible to decay, and many trees above 40 inches in diameter on the forest are so rotten as to be valueless, even for cordwood.

In the latter case, age is supplanted by diameter, which answers perfectly well if diameter invariably corresponds to age.

Barrington Moore and R. L. Rogers⁴ incidentally give some interesting notes on the age of infection of balsam fir, which on the

¹ Greenamyre, H. H. The composite type on the Apache National Forest. U. S. Dept. Agr., Forest Serv. Bul. 125, 32 pp., 4 figs., 1913. (See p. 31.)

² Munger, T. T. The growth and management of Douglas fir in the Pacific Northwest. U. S. Dept. Agr., Forest Serv. Circ. 175, 27 pp., 4 figs., 1911. (See p. 10.)

³ Burns, Findley. The Crater National Forest. U. S. Dept. Agr., Forest Serv. Bul. 100, 20 pp., 4 pls., 1911. (See p. 12.)

⁴ Moore, Barrington, and Rogers, R. L. Notes on balsam fir. *In* Forestry Quart., v. 5, no. 1, pp. 41-50, 1907.

area investigated was 50 years in pure stands and 85 years when mixed with hardwoods. They speak of butt-rot only, without specifying the cause; unfortunately, the numerical basis from which their figures are derived and their methods are not given.

The bearing on management of the age at which decay becomes a seriously damaging factor is very rarely realized.

Clapp,¹ in speaking of incense cedar and white fir, clearly recognizes that where these "inferior" species are also defective, "an attempt should be made, at least in selection stands, to reduce their rotation to one which will produce sound timber."

In a recent article, D. T. Mason² advocates a rotation of 100 years for western white pine, on the ground that this species on the average gives a maximum yield at this age and that from about the same age fungi, and particularly insects, generally succeed in doing a large amount of damage.

It would serve no purpose to continue quoting the few and scattered notes on the relation of age to decay, of a similar indefinite nature found in American literature. By way of consolation, it may be said that foreign literature does not abound very much more than our own in definite information regarding this point. Although the importance of the age at which forest trees are most liable to attack from heartwood-destroying fungi is frequently hinted at in German literature, Martin³ is the only German forester who, to the knowledge of the writer, has given more than a cursory discussion of the relation of this age to rotation. In speaking of the immense damage done in Prussian pine forests by *Trametes pini*, he attempts to show from somewhat meager material how the increase in loss from this cause should lower the rotation.

All computations of the amount of decay in German forests must necessarily be incomplete, since from an early age all undesirable individuals, including, as a matter of course, all trees with visible signs of decay, are eliminated in improvement cuttings. The result is a stand of a comparatively high degree of soundness. Even in such stands Martin finds (p. 688) that in a given district the percentage of decay in wood good for fuel only in the 100-year class was 11, in the 120-year class 22, in the 130-year class 31, in the 140-year class 37, and in the 160-year class 42. He points out that in unsound stands the felling age must be lowered in order to secure the maximum income. Martin⁴ again discussed similar ideas in 1910.

¹ Clapp, E. H. Silvicultural systems for western yellow pine. *In* Proc. Soc. Amer. Forest., v. 7, no. 2, pp. 168-176, 1912. (See p. 175.)

² Mason, D. T. Management of western white pine. *In* Proc. Soc. Amer. Forest., v. 9, no. 1, pp. 59-68, 1914.

³ Martin. Der Einfluss des Baumschwammes auf die Umtriebszeit der Kiefer. (Kritische Vergleichung der wichtigsten forsttechnischen und forstpolitischen Massnahmen deutscher und ausserdeutscher Forstverwaltungen.) *In* Ztschr. Forst- u. Jagdw., Jahrg. 35, 1903, Heft. 11, pp. 685-690.

⁴ Martin. Die Umtriebszeit der Kiefer in den Staatsforsten von Preussen, Bayern, Elsass-Lothringen, Hessen und Anhalt. *In* Forstw. Centrbl., Jahrg. 54, 1910, Heft 7, pp. 363-387.

Möller¹ touches upon the same point in a general way, without trying to give the problem a more solid basis by exact material. The following sentence is worth quoting:

Whilst the mean annual increment of the stand is slowly decreasing, the mean annual increment of decay is steadily on the increase.

Here is the clue to the proper silvicultural valuation of cutting cycles or rotation on a pathological basis. The time at which a tree or a stand is to be cut may range from a comparatively low age to the age of maximum production of lumber, according to the special needs the forester has in view; but the upper limit of this range should not lie beyond the period at which the gain from increment is offset by loss from decay, irrespective of the ideal amount of timber a sound tree or stand might produce under favorable conditions. Not to cut a tree or a stand in which increment is offset or exceeded by loss from decay, where cutting is possible, constitutes an unsilvicultural act. Gilman² informs us that silver fir in the Black Forest, Baden, Germany, "is unable to stand a long rotation, for after 100 years the per cent of rotten timber increases greatly." Here, the influence of loss from decay on rotation is clearly shown; but it is to be noted that the loss factor is derived in a purely empirical way and is not based on exact studies. Hemmann³ has published some interesting and exact studies on the damage done by *Trametes pini* in Scotch pine in a small area under regular management; that is, where the disease was partly eliminated by improvement cuttings.

All this somewhat scanty European material, valuable though it undoubtedly is for transatlantic forestry, is of very little help to us. What holds good for the managed forest raised in a century of careful nursing can not serve for more than a clue in genuinely or practically virgin forests, whether they be located in the United States, in Canada, in Chile, in India, or in Siberia. Again we are confronted with the necessity of working out our own problems in our national forests.

INFERIOR SPECIES.

Most of the timbered parts of the national forests, especially in the West, are practically virgin, seriously injured by fire, composed of even-aged or many-aged stands, and generally of more than one species, which are more or less exposed to heart rot caused by one or more specific fungi.

¹ Möller, A. Über die Notwendigkeit und Möglichkeit wirksamer Bekämpfung des Kiefernbaumschwammes *Trametes pini* (Thore) Fries. In *Ztschr. Forst- u. Jagdw.*, Jahrg. 36, 1904, pp. 677-715. (See p. 712.)

² Gilman, E. C. V. Forest types of Baden. In *Forestry Quart.*, v. 10, no. 3, pp. 440-457, 1912. (See p. 452.)

³ Hemmann. Über den Schaden des Kiefernbaumschwammes. In *Allg. Forst- u. Jagdztg.*, Jahrg. 81, pp. 326-341, 1905.

A systematic study of the relative position occupied by the heart-rot factor in the economy of the forest presupposes a knowledge of the morphology and biology of the specific fungi attacking the species of which the forest is made up. Morphologically, most fungi of economic importance are well known; biologically, there is much left to be learned. The susceptibility of each host species to specific attack, the age at which a given species becomes liable to attack by the fungi adapted to live on it, the age at which a given species is liable to suffer appreciable loss from this source, the relation of accessory factors in the tree and outside of it to fungus growth, the relative loss caused by each fungus in its specific host—all these are fundamental problems which must be solved for every important fungus on every commercial species of our forest trees. So far, no definite and clear, comprehensive answer can be given to any one of these questions.

In determining upon a suitable starting point in the overwhelmingly large amount of work before us, the question is that of deciding where such work is most needed at the present time.

Leaving out of consideration such species as bigtree (*Sequoia gigantea*), which is never cut in national forests, and redwood (*Sequoia sempervirens*), which is hardly represented in national forests, the commercial timber of the national forests in the western part of the United States is composed of coniferous trees, such as pine, larch, spruce, fir, Douglas fir, hemlock, incense cedar, and western white cedar. They constitute the goods the Government has to offer for sale. Of these the pines cause least trouble. Pine lumber is eagerly sought and pays good prices; moreover, the loss from decay is comparatively small. In Government timber sales there is never any difficulty about pine timber; the more the Government has to sell on a given tract the better. Not so with the so-called "inferior species."

The term "inferior or undesirable species," as it is generally applied, is originally not a technical one. It is meant to designate those more or less heavily represented commercial species which suffer from a distinct prejudice on the part of the purchaser. If we could grow sound incense cedar, for instance, there would be a ready market and a good price for every foot, board measure, of it that the Government could offer on timber sales. Distinction should be made between species which actually yield technically poor lumber, even if sound, and species, on the other hand, which when clear and sound yield valuable material, but which are in general underrated by the purchasing public on account of the extraordinary prevalence of decay. An example of the first class is eastern hemlock. An example of the second class is incense cedar, which, although of excellent quality when sound, suffers from a very bad reputation among lumbermen,

because it is so very commonly rendered useless by dry-rot or pin-rot. The numerically and economically most important species of the accessible merchantable national forests in southern Oregon and California are sugar pine, Jeffrey and yellow pine, Douglas fir, white fir, and incense cedar. To these may be added, for certain localities, lodgepole pine, red and Shasta firs, western larch, Sitka spruce, western hemlock, and western red cedar. Of the six main species, all three pines command good prices. They are comparatively free from heart rot. White fir and incense cedar are in general so badly defective that, as Clapp¹ states, they are "under present conditions almost a drug on the market." Douglas fir stands in a class by itself. The value of its timber is well known; in fact, it competes with pine timber as far as quality for many purposes is concerned. On the other hand, Douglas fir is in a far higher degree susceptible to the attacks of several heartwood-destroying fungi, and, although it is not classed among the inferior species, the very prevalence of decay makes it less desirable than the pines, from a silvicultural point of view.

Incense cedar and white fir are frankly classed as inferior. Whether this view is correct or not, we must reckon with it as a powerful factor of influence in all timber sales where these species occur. They are the lower grade by-products of the factory, the production of which can not be stopped; it goes on in spite of what we may wish or what we may do. The logical conclusion appears to be, then, to concentrate all efforts on detailed and comprehensive studies of the properties of these by-products, desirable or undesirable, and to incorporate the results in a rational system of management, rather than to attempt to stop their production. The attitude of American foresters toward these and similar species is undoubtedly changing. There was a time when they were considered little better than weeds, to be gotten rid of as soon as possible and to be kept out of the forest wherever possible. This concept is giving room more and more to a consideration of how best to regulate the unavoidable reproduction of both species and how best to utilize the timber they produce.

The so-called inferior or undesirable species have their very definite place in the ecology of the mixed forest, and many examples could be cited from European experience of the disastrous results of an artificial change in representation of species and reduction of the mixed stand to a pure stand composed of an apparently more desirable species, without due consideration to the local soil and climatic conditions. Greeley² seven years ago expressed the opinion that "it is

¹ Clapp, E. H. Silvicultural systems for western yellow pine. *In Proc. Soc. Amer. Forest.*, v. 7, no. 2, pp. 168-176, 1912. (See p. 175.)

² Greeley, W. B. A rough system of management for forest lands in the western Sierras. *In Proc. Soc. Amer. Forest.*, v. 2, no. 2, pp. 103-114, 1907. (See p. 112.)

both impossible and undesirable to eliminate these species altogether." He specifically names white fir and incense cedar. Their aggressiveness makes it impossible to eliminate them, even if this were desirable. But more than one species, not so many years ago considered inferior, has now come into its own. The history of the lumber markets of Europe and our own country shows conclusively that with closer utilization necessitated by the growing scarcity of timber, the value of lower grades, as well as of so-called inferior species, is advancing more rapidly than that of upper grades or more valuable species. In the case of incense cedar this evolution may be watched at the present time. Up to a very short time ago incense cedar was "almost a drug on the market;" now even very short logs when sound are utilized for pencil wood and priced accordingly.

Concentration of study on the inferior species, therefore, promises the most immediately applicable results.

METHODS OF INVESTIGATION.

CHOICE OF SPECIES AND SITE.

Forestry is not interested primarily in the morphology and life history of a given heartwood-destroying fungus. Such studies, though indispensable and of the highest value, belong to an altogether different realm of science. The forester thinks in terms of trees, not of fungi; he concentrates on timber species to be protected or utilized, not on parasitic organisms, however interesting they may be from a mycological point of view. If forest pathology is ever to be of any value to practical forestry, all work and all conclusions must be focused on the tree, the species, as a producer of timber values and as a member of the forest community.

The fact that the same species may be subject to serious loss from several fungi and that the same fungus often works differently in different host trees complicates the difficulties naturally connected with all work for which a basis first had to be constructed. Partly for this reason, the writer first worked on incense cedar, which, so far as known, has only one heartwood parasite, *Polyporus amarus*. The studies described in the following pages were concentrated on white fir, because its management presents, perhaps, the most embarrassing problem of to-day on the Pacific coast and because, in by far the greater number of cases, serious loss is caused by one fungus only, *Echinodonium tinctorium*.

After deciding upon the species to be investigated, the choice of the sites for the study becomes the main question. One single type will probably yield interesting clues, but the result can not with impunity be applied to all sites and types within the range of the species. It is clear that studies within what might be termed the merchantable range of the species must be most important from a practical point of view. But inside of the merchantable range the species is subject to

so many varying conditions with regard to soil, climate, admixture of the species, and representation that here again typical areas must be chosen for independent studies. The more diversified the types studied and the greater the number of trees per type and in the aggregate, the more reliable will be the results.

The choice of the particular area to be studied is, of course, important. The unit of study should be representative, typical for the larger unit. In general it will not be difficult, with some care, to make the proper choice.

The result of the writer's studies, still unpublished, on the critical age of incense cedar served to work out the methods which should be applied in a modified form to the at present more important investigations on white fir. European precedent could not be used; Martin, Möller, and Hemmann worked on managed forests. New methods to suit our conditions had to be evolved.

The only satisfactory result could be expected from careful dissection and analysis of as large a number as possible of trees of different ages. Unlike other investigative work, studies of this kind can not well be carried out on timber-sales areas where the actual felling and bucking of the trees is done by the purchaser. The purchaser is none too willing to cut trees containing rot unless he is compelled to do so; much less does he care to buck such trees, which, after all, are the ones from which we must expect most valuable instruction. He is not obliged to cut trees below a certain diameter limit, which, of course, can not be left out. All this is particularly true for the so-called inferior species, the handling of which often comes so near being a loss to the purchaser that any additional cost would work a distinct hardship. For the same reason it is impossible to have the trees on timber-sales areas bucked in odd log lengths, as dictated by the irregular and varying extent of the decay. As will be seen, a few of the notes used for this study are incomplete, because they had to be taken in connection with timber sales.

It becomes necessary, therefore, to carry on investigations of this kind on representative areas chosen for the purpose and to have the systematic cutting and dissecting of the trees done by crews, involving much work and a large expenditure. This way of handling the problem has proved to be the only feasible one; and, as long as immediate results may be expected, which if properly applied must lead to very considerable savings as well as to progress in silvicultural management and forest regulation, the expense and work seem to be justified.

FIELD METHODS.

Before the actual felling begins, notes are taken first on the larger forest unit of which the area to be studied forms a part, such as elevation, climate, water table, soil in general, history (lightning and

forest fires), composition, representation of species, ground cover, possibilities of future logging operations as a first step toward regulation, and local valuation of the species; more detailed notes of a similar nature then describe the particular type and stand which is the object of the study.

When a new species is to be studied, trees of all sizes and all conditions must be cut. It is absolutely necessary constantly to guard against picking out trees either because they appear sound or because they are liable to contain decay. According to the attitude of mind of the investigator there will always be a tendency, conscious or subconscious, to think of the final result and accordingly to choose particular trees for felling. The personal factor must necessarily influence the result of the equation and can not be warned against too emphatically.

Correctness and accuracy in detail are the basis of any scientific work worthy of the name. Where the one chief aim is to substitute reliable figures for guesswork, to establish facts, from which conservative interpretation may derive certain working rules, observations and measurements can not go too far in detail and exactness. On the basis of experiences in the incense-cedar studies, a printed sheet was prepared, to be used in a loose-leaf binder of pocket size, in which a set of standard notes was to be entered. Each sheet contains the notes for one tree only.

The first notes to be taken on a tree chosen for analysis are general; they are taken before the tree is felled. Slope, exposure, soil composition, and moisture are taken for the individual tree; the next notes concern the outward appearance of the tree, crown class, as far as can be determined, condition of the bole, whether forked or leaning, presence and degree of fire scars, resin flow on butt or bole, swellings, sporophores of fungi, condition of the crown, development and state of health; in short, all notes that can and should be taken from the standing tree. During this time an assistant takes the diameter breast high and sets the fellers to work. The notes on the bole and crown are completed when the tree is down. They concern the presence of mistletoes or needle diseases, witches'-brooms of any kind, their number and relative importance, presence and extent of lightning injury, condition of top, and similar data that might have a bearing on the pathology of the species. It goes without saying that the tree is felled at the regulation stump height of 18 inches, never higher unless absolutely unavoidable. The assistant now measures the height of the tree from the ground and counts the age at the stump. This, of course, does not give the true age; but instead of adding, more or less at random, a small number of years corresponding to the height of the stump, it seems advisable to accept the count at the stump as the age. The fewer the figures based on an estimate

that are included in our computations, the narrower will be the margin of error. Besides, in practical work, the age is generally counted at a stump height of 18 inches, and, since for all purposes of management we have to deal with the standing tree where diameter is the only indicator of age, it is of little importance whether the age counted is absolute, within narrow limits, as long as all figures are directly comparable with each other. Moreover, in practice it is impossible to have all trees cut at exactly 18 inches. With the greatest of care, the stump height will vary. It is an easy matter, where desired, to add a number of years corresponding to stump height as soon as reliable figures, which now are lacking, are obtainable.

The limbs and branches are now lopped off and the brush piled for burning.

In the bucking of the bole some judgment should be used, guided by the object of the study. We want to find all traces of decay in the bole and take exact measurements of them. Obviously, then, the aim of the dissection must be to open up the tree in such a way that no decay can escape the observer. It would not do, therefore, to buck all trees in even log lengths of the usual commercial measures. A straight, clean bole without any blemish whatever is bucked in 16-foot logs, which then are individually split; this will, as a rule, bring out any hidden decay. Both the cross sections at the opened surfaces of the split wood must be searched very carefully for any abnormal sign. This makes full knowledge of the properties and aspect of the normal wood a prerequisite. In the beginning, therefore, it is advisable first to study very closely the sound, normal wood of the species, until the operator is able to detect at a glance and automatically any deviation from the normal. The success of the study hinges upon the development of personal skill in judging wood. In order to prevent the dulling of this sense during the course of the work, check studies of perfectly sound wood will prove very beneficial. Any slight real or apparent deviation from the normal in physical properties or aspect, particularly in color, must be followed, of course, to its source.

Trees without any blemish are rare; generally there is either some irregularity in form, fork, unusually heavy branching, or there are sporophores of fungi, badly healed-over branch stubs, swellings, depressions, catfaces, fire scars, lightning scars, or frost cracks and frost ridges. In choosing the proper places for bucking, it is generally advisable to start at the most salient malformations or defects; they will often lead to the focus of decay, if there is any. In case of failure, the less prominent defects are investigated, and so on down the line until there is no doubt left that no decay is present in the bole. Particular attention must be given to branch stubs, which, by extending through the sapwood to the outside of the tree, offer an easy

entrance into the heartwood. After infection has taken place in this manner, the mycelium grows in the heartwood. Before sporophores are formed it is often impossible to locate the presence of the mycelium in the tree. This is particularly true for quite young fungus plants, and the possibility that the beginnings of decay may be hidden in a log, both ends of which are perfectly sound, must ever be present in the mind of the operator. It is impossible, except by mere chance, to detect the very first stages in the field. As soon as the fungus plant, the mycelium, has reached a certain stage of development, represented by visible alterations of the wood, there is no excuse for overlooking it. As a rule, the oldest part of the focus of infection shows the strongest evidence of fungus growth expressed in what we call decay. Decayed stubs are a valuable index as to decay in the tree, although there are cases where, for unknown reasons, the infection does not, or only very slowly, result in more extended decay. Duesberg¹ has advocated the location of infected trees by the presence of diseased branch stubs. Such decayed branch stubs may also correspond to that stage of development of the mycelium just before the formation of sporophores through the stub takes place. In this case also decayed branch stubs will be most valuable in detecting heart rot in the bole.

If decay is found, it is followed throughout its entire extent by splitting the logs with wedges and with the ax. To avoid this often very tedious and time-consuming work, splitting with black powder has been tried, with rather unsatisfactory results. In partly decayed logs the splitting is very irregular, and the wood surfaces are badly stained and blackened, the stain generally interfering with the inspection of the wood. When the full extent of the decay is determined, notes are taken on the character of the discoloration or decay and on the stage of development, and the extent is carefully measured. For studies of this kind it will often be sufficient to note the extent in length in linear feet, under the assumption that in low-priced species any lumber that might be cut from an affected part of the bole will not pay for its transportation to the mill. In higher grade species the lateral extent must always be considered.

This complete and detailed dissection usually allows the tracing of the decay to some point of entrance, whether fire scar, lightning wounds, frost cracks, or branch stubs. The result is entered on the sheet. Finally, any notes not specially foreseen on the sheet are entered under "Remarks."

As a general principle, all observations that can be expressed numerically must be given in figures. It is essential that all esti-

¹ Duesberg. Das Aufsuchen von Schwammstämmen in Kiefernbeständen vor der Ausbildung von Fruchtkörpern. In *Ztschr. Forst- u. Jagdw.*, Jahrg. 44, Heft 1, pp. 42-43, 1912. Reviewed in *Forestry Quart.*, v. 11, p. 251, 1913.

mating should be reduced to a minimum. In order to render this unavoidable minimum, which undoubtedly constitutes a source of error, as innocuous as possible, the operator must constantly be on the guard against any variations of his standard by which he is guided, consciously or subconsciously, and from time to time check up on this standard. The notes to be taken by estimate concern degree or grade. Soil moisture, seriousness of wounding by fire, degree of resin flow (whether light or heavy), condition of crown (for example, unhealthy color or thin foliage and the presence and degree of needle diseases in their bearing on the thriftiness of the tree), degree of discoloration of the wood—all these can be expressed in figures only with difficulty. Even if a scale of 1 to 10 is adopted for these purposes it is extremely difficult to decide whether the change of color of the wood under the influence of the fungus is to be classed as 6 or 7. The writer therefore has adopted a simpler system, which, while far from being exact, at least avoids gross errors and at the same time is graphically clear and sufficiently elastic to cover all cases of importance. It expresses the information asked for on the sheets with the aid of crosses and dashes. A dash after "Fire scars," for instance, is negative; there is no fire scar. One cross, x, is simply affirmative; there is fire injury, but it is not to be considered as serious. Two crosses, xx, indicate that the fire injury is fairly bad, distinctly beyond the mere presence of an injury. Three crosses, xxx, emphasize the damage; the fire injury is unusually large and severe. By putting the crosses in parentheses, (x), or x (x), or by hyphenating two consecutive degrees, x-xx, intermediate grades may be given when desirable; and finally the last grade, xxxx, can be used in very extraordinary cases for emphasis. In general, x, xx, and xxx will answer the purpose. Thus, the estimate is really reduced to a simple system of three grades, which allows for a more constant mental reference to the standard. Whenever necessary or feasible, special notes or measurements are entered after the crosses. This system is also used in our tables. With the exception given above, all these notes are taken by the chief of the party. Meantime, the assistant counts the age and diameter at every cross section, takes growth measurements, measures the width of sapwood and the length of the sections, and records such other data as may present themselves in the course of the work.

In complicated cases, drawings or notes are added on blank sheets bearing the numbers of the trees.

PATHOLOGY OF WHITE FIR.

The studies on white fir presented in the following pages are not meant to give definite results valid for the entire range of the species. They were primarily intended to develop the more practical methods

to be employed and secondarily to gain reliable material to be used in a chain of similar studies on different types, from which conservative interpretation may derive final conclusions. They are given here as examples only, as illustrations of the general considerations presented in this bulletin. Since making these studies, others on a larger scale and on different types in different parts of the range of white fir were carried out with improved methods during the summer of 1913.

A short review of our present knowledge of the pathology of white fir will be of help in the discussion and interpretation of the data presented in this paper.

White fir (*Abies concolor* (Gord.) Parry) can not be called a decadent species; on the contrary, it is very aggressive and possesses remarkable elasticity and resistance to injurious influences. Its tolerance to shade is well known. Not only does it survive dense shading to a high age but it responds readily to light and then reaches considerable diameter and height in perfect health, provided it has not been seriously wounded and infected. The oldest tree examined in this study was 258 years old; it was badly suppressed and but 67 feet high with a diameter breast high of 17.4 inches. In the trees tallied between the ages of 130 and 140 years, the diameter breast high varied from 8.8 to 30.7 inches and the height from 47.5 feet to 125 feet.

In speaking of tolerance which allows suppressed trees to reach a high age under the most unfavorable conditions and with a minimum of annual growth, the behavior of the species with relation to light is generally meant; but this toning down of the life functions of the tree, visibly expressed in growth, very often has nothing to do with lack of light. A tree may become suppressed to the lower limits of its tolerance by any agent severely attacking any of its vital organs. Of these, the organs of the crown are both most easily accessible and most sensitive; hence, the heavy damage resulting from a serious attack by insects devouring and killing the foliage or by leaf-inhabiting fungi. White fir is subject to a disease of the foliage caused by *Lophodermium nervisequium*, which often kills all needles except those of the current year's growth. The loss in foliage surface, and therefore in photosynthetic capacity, may suppress a white fir just as lack of light would. Witches'-brooms caused by *Peridermium elatinum* on white fir are not common. They are very rarely of such development on the tree that they should be classed as an injurious factor to be reckoned with. Incidentally, it should be mentioned that the swellings and cankers so commonly connected with *Peridermium elatinum* on *Abies pectinata* in Europe are unknown in *Abies concolor*. On the other hand, very similar swellings and cankers caused on white fir by *Razoumofskyia abietina* Englm. are extremely common. The

actual connection is readily established by either the living mistletoe growing out from the swellings or by the small cuplike remains of the stem bases. The swellings render the affected part of the bole unmerchantable. When they break open into what are termed cankers, infection by fungi very readily takes place and a focus of heart rot forms, very much as in the case of *Peridermium elatinum* on *Abies pectinata* where *Polyporus hartigii* and *Agaricus adiposus*¹ commonly start from cankers caused by the rust fungus.

The mistletoe cankers very often are the cause of white-fir stems breaking off in a storm, just as *Peridermium* cankers affect *Abies pectinata*. This mistletoe is more generally found in the middle or lower parts of the crown; infection takes place only on the very youngest twigs.

Another mistletoe (*Phoradendron bolleanum* (Seeman) Coville) nests high up in the top. It often kills the leader; volunteers spring up, which are frequently killed in their turn. Considered in its relation to the totality of leaf functions, the loss from a killing of the leaders can not be very serious, although it may count in combination with other injurious agencies. The same is true for the host of minor parasites and injuries to which the peripheral growing parts—in contrast to the column of wood—are exposed.

We have seen that the wood of the living tree itself is generally immune to attack from heartwood-destroying fungi as long as it is protected by bark and sapwood. The few exceptions, it seems, are of no great importance in the case of *Abies concolor*. *Pholiota flammans* is not uncommonly found in white fir and seems to take the place of *Armillaria mellea*. The exact damage done is still to be studied. *Fomes annosus* is not yet reported on white fir to the writer's knowledge. *Polyporus schweinitzii* is not common on the species. All other fungi causing decay can not enter the living tree except through some opening, as far as is known at present.

In white fir, as in other coniferous trees, small superficial wounds are readily covered over with resin from the bark; this natural dressing does not allow fungus spores to germinate or the hyphæ to develop after germination. Now, white fir is distinctly poor in resin. Large superficial wounds may therefore prove to be more serious. If the bark is destroyed, the cambium is killed and the sapwood dries out and cracks. Through these cracks air gains access to the interior of the tree and must in some way alter the chemistry and physics of the heartwood. The spores of heartwood-destroying fungi lodge in the cracks and upon germination may find a well-prepared substratum in the heartwood. Fungi, like all plants, make certain specific demands as to the chemical composition, water content, oxygen, etc., of the substratum they live on. Given the proper temperature

¹ Hartig, Robert. Lehrbuch der Pflanzenkrankheiten. Ed. 3, p. 153. Berlin, 1900

and the species of wood on which, for instance, a fungus like *Echinodontium tinctorium* (Indian-paint fungus), the most common destroyer of white-fir heartwood, can exist, its growth will still be dependent on the presence of heartwood of a certain character and on the water content of the heartwood. This is evidenced by the fact that decay is so commonly found in concentric development at a certain distance from the sapwood. The heartwood contains water in varying degrees, although it does not lift water like sapwood. But there is nothing surprising or irrational about the assumption that the water content of the heartwood will depend more or less on the water movement in the sapwood. The water in the heartwood of conifers is found in the membranes of the tracheids, not in the lumina. In a normal sound tree, heartwood of a given age and diameter surrounded by sapwood of normal width, corresponding to a certain crown development, will contain approximately a standard amount of water. Decrease in crown activity through some cause or another (suppression, injury to the crown, etc.) will soon be expressed in a rapid progress of heartwood formation, leaving only a narrow strip of sapwood, through which very much less water will move upward to the crown than in the normal tree. We may safely assume that the water content of the heartwood will change to a certain degree with the amount of water moved upward in the sapwood. The water content of the sapwood changes, furthermore, with age, and also with the season. Both changes must also appear, although in a far less degree, in the heartwood. Münch¹ has emphasized, in a series of very interesting papers, the relation of wood-inhabiting fungi to the water and air content of the host tissues. Water-logged tissues are inaccessible to these fungi; a certain minimum of air, as Münch expresses it, must be present in the tissue in order to allow the development of the hyphæ.

Variations in the water contained by imbibition in the cell membranes must influence the degree of humidity of the air in the lumen of the cell itself; it is quite probable that this factor also plays a rôle in the distribution of hyphæ in the wood.

What percentage of water in the cell membranes and of air in the lumina of the heartwood presents the optimum for the development of *Echinodontium tinctorium* and other similar fungi we do not know; but evidently there must be an optimum, a maximum, and a minimum. Any factor influencing the quota of water and air in the heartwood must, therefore, be of great importance. Cracks in the sapwood

¹ Münch, Ernst. Die Blaufäule des Nadelholzes. *In* Naturw. Ztschr. Land- u. Forstw., Jahrg. 5, 1907, Heft 11, pp. 531-573; Jahrg. 6, 1908, Heft. 1, pp. 32-47, 33 figs.; Heft. 6, pp. 297-323.

Münch, Ernst. Untersuchungen über Immunität und Krankheitsempfänglichkeit der Holzpflanzen. *In* Naturw. Ztschr. Forst- Land u. w., Jahrg. 7, 1909, Heft 1, pp. 54-75, 5 figs.; Heft 2, pp. 87-114; Heft 3, pp. 129-160.

Münch, Ernst. Über krankhafte Kernbildung. *In* Naturw. Ztschr. Forst- u. Landw., Jahrg. 8, 1910, Heft 11, pp. 533-547; Heft 12, pp. 553-569, 2 figs.

reaching to the heartwood admit air, and by evaporation change the water content of the heartwood; by oxidation, changes in its chemistry probably also take place.

The change must necessarily be intensified, the more serious the injury. Wounds exposing the heartwood heal over very slowly, and the heartwood which receives all its water from the sapwood must be modified very markedly in its chemistry and physics, particularly in its water and oxygen content, by the long exposure to the air. Moreover, from the time the injury happened until the time the wound is completely healed the heartwood is directly exposed to inoculation from spores of wood-destroying fungi adapted to white fir. Although the production of spores by a sporophore is enormous, by far the greater number are carried by air currents to places where they can not germinate for lack of moisture; many are intercepted by the natural screen ("forest screen") formed by the foliage and trunks of uninjured trees or by trees to which they are not adapted, and only a very small number finally land in the cracks of exposed sapwood or on exposed heartwood of white fir of the proper age. Of these, again, a very small percentage find temperature and moisture favorable for germination. This explains the fact that so many trees, although badly wounded, are not infected. But it stands to reason that every year during which the heartwood remains exposed adds to the danger of the tree becoming infected.

By far the deepest wounds are caused by fire. Although in white fir the danger in repeated fires feeding on the pitch flow following a first injury is comparatively slight, and although the lack of resin in the wood does not favor the hollowing out of the interior of the tree as it does in yellow pine, fire frequently causes very long wounds, which reach into the heartwood.

Spores can gain entrance to the heartwood through open frost cracks. Low temperatures and sudden drops of temperature are common throughout the range of white fir. Inside of the range they are more or less confined to certain localities and zones.

Lightning in white fir generally causes more or less superficial wounds. The peculiar injuries to be traced to lightning in white fir present many interesting features. Here we are only interested in injury which might lead to the infection of the heartwood. As in yellow pine, lightning sometimes tears long strips of bark off the tree and leaves the cambium and sapwood unprotected. In such cases both die and dry out, with the result that cracks in the sapwood lead into the interior of the tree. Smaller superficial lightning wounds locally kill the sapwood, which is very commonly attacked by secondary fungi, which do not do very serious damage. However, logs with lightning injury of this kind are liable to be thrown out as culls, although they generally contain some sound heartwood.

Other causes of serious wounds are comparatively rare. Occasionally a falling tree will brush off part of the bark of its neighbor. If the wound is large, the exposed sapwood dries out, cracks, and the heartwood becomes exposed. Very rarely a living tree shows signs of early girdling by rodents. Girdled trees as a rule are killed within a short time.

With very few exceptions the entrance of the fungus into the tree can be traced to one or more of the wounds just discussed. Occasionally, however, a tree showing no wounding at all is found to be decayed. In such cases the only means of entrance for the wood-destroying organism is through knots.

White fir prunes itself very poorly; the wood of the twigs is tough, hard, and resistant, and the branches do not break off very readily. Later, dead twigs may break off; in the cracks of the wood of the stubs spores of fungi may find proper conditions for germination and, once established, use the pin knot as a bridge from the exterior of the tree through the bark and sapwood into the heartwood. This is particularly true for twigs in which heartwood formation has begun. In this sense the opening afforded to fungi by a pin knot that is not healed over may be likened to a wound. The opening formed by the pin knot, however, is too small to materially influence the chemistry and physics of the heartwood of the tree.

White fir is not exposed to a great number of heart-rot fungi. *Polyporus schweinitzii* is not common. *Polyporus sulphureus* and *Trametes pini* are rather rare. The parasitism of *Fomes pinicola* is not fully established, at least not in white fir. The writer has found it on thrifty sugar pine in central California, where it was undoubtedly parasitic in the sense of attacking the sound heartwood of living trees through an open fire scar and extending toward the sapwood. There would be no incongruity in assuming that it may also occur parasitically on white fir; in fact, a number of observations rather speak for the correctness of this assumption.

By far the most serious danger to white fir throughout its range comes from *Echinodontium tinctorium* Ellis and Ev. This fungus seems to be particularly adapted to *Abies concolor* and does not appear on many other species. In California it is, though not very often, found on *Abies magnifica shastensis* and also rarely on Douglas fir. This fungus must therefore be considered as the chief fungus enemy of white fir. The sporophores are easily recognized. They are rather large, from 2 to 10, 12, and more inches in width (measured horizontally from side to side where they are attached to the tree), distinctly hoof shaped, with a black, dull, cracked, rough upper surface, and a lighter, grayish, level under surface, which is thickly set with hard, coarse spines. In young specimens the under surface is whitish and rather dædaloid prior to breaking up into spines. The

interior of the sporophore is vividly rusty red. This rusty color is most characteristic of the fungus and repeats itself very often in the decayed tissues of the host. The sporophores are never formed on the bark of the tree; invariably they appear from the under side of stubs of dead twigs or branches, and commonly the rusty color can be followed through these stubs or knots. As the sporophore is nothing but the fruiting body of the mature fungus plant living in the heartwood of the tree, which alone it is able to attack, every sporophore is a certain sign of far-reaching decay in the tree. The typical rot may be characterized as a stringy brown rot. Wood in this stage of decomposition is brown, with rusty reddish streaks, and becomes distinctly fibrous and stringy. Following the rot away from its maximum of development, we find wood still brown, with rusty streaks, but quite firm. Farther away, the brown color becomes less noticeable, the rusty color disappears, and finally we come to a point where the wood seems to be sound enough to be sent to the mill. A little care exercised in examination, however, will show in this seemingly sound wood the presence of small light-brownish spots and discolorations, particularly in the summer wood, intermingled with horizontal burrows, which at first glance could almost be taken for very shallow insect burrows. The burrows are not easily detected on a cross section. The small brown spots, which give the wood a faintly brown, mottled appearance, cause the entire cross section to be slightly darker than normal and discolored; but they show up very much more clearly in a longitudinal section. A small piece pried out of the end of the log with a hatchet or strong knife gives sufficient information about the real state of health of the log. This timber at present invariably goes to the mill and without doubt furnishes the lumber that, after being sawed, dries out and by becoming brittle causes the well-known prejudice against this species. It is often characterized by a peculiar sour smell and by a spongy consistency of the wood.

Cull from decay in white fir, therefore, includes not only typical rot but also this discolored material, which, although not distinctly rotten, is already under the influence of the advance guard of the fungus mycelium and will become completely decayed later on. For this stage of incipient, or, better, latent decay, the writer proposes the term "advance rot," which is used throughout this bulletin.

DESCRIPTION OF AREAS.

The three areas chosen for investigation are located on the Crater National Forest, in southwestern Oregon, all of them in the neighborhood of the Upper Klamath Lake, a large shallow basin with vast swamps, into which unusually large springs of clear cold water empty themselves. Very few streams of running water come from the

surrounding mountains. Dense timber frames the swamps and extends up the slopes to the mountain tops. The elevation of all three tracts varies from 4,150 to about 4,400 feet. Low winter temperatures and severe lightning storms are frequent in the entire region. Two of the tracts, the Pelican Bay Lumber Co. sales area and the Odessa ranger-station tract, are situated on the west shore of the lake. They are about 2 miles apart and present conditions so much the same that they can be considered as one.

The Pelican Bay tract on the west side of Pelican Bay lies, as far as the area covered by this study is concerned, along the slopes; the aspect is east to northeast. That is, it is exposed to cold wintry winds, sweeping unbroken across Upper Klamath Lake. We may expect frost injury. The volcanic soil is fairly deep and loose; the humus layer is rather shallow. There are no rock outcrops. The underbrush is composed of *Ceanothus*, manzanita, and some chinquapin.

The Odessa ranger-station tract is far less steep than the Pelican Bay tract. A considerable part of it is a gentle slope, almost level. The general aspect is north; presumably the tract is less exposed to sweeping winds of very low temperature. The soil is decomposed lava, but richer in humus than the Pelican Bay tract. Outcrops of rock are frequent. There are a number of large springs in the neighborhood. The underbrush is rather dense and is composed of *Amelanchier alnifolia*, *Ceanothus velutinus*, with some *Salix* sp.; the ground cover consists of *Ceanothus prostratus*, *Berberis aquifolium*, and *Symphoricarpos racemosa*.

The third tract, the Otter & Burns sales area, lies about 15 miles north of the north end of Upper Klamath Lake. The tract is level, the soil very loose, sandy, decomposed pumice, with no indication of rock. Under the influence of the Fort Klamath Valley with its swamps, the atmospheric humidity is rather high, as is evidenced by the rich lichen flora, *Alectoria fremontii* being common. Thus the immediate surface of the soil is kept damp, and litter disintegrates very rapidly. The humus is about 1 to 2 inches deep; the soil immediately underlying it is remarkably well drained. The rapid humification in the top layers favors the development of mycorrhiza on the roots of white fir in surface strata. White fir seedlings show a thick matting of mycorrhiza, confined to the same strata of a certain humification, and a very long taproot seeking water. Yellow-pine seedlings also develop a taproot, but the mycorrhiza rootlets are found at a greater depth than those of white fir. They are not as closely bunched as in white fir and are distributed over a larger area in a vertical direction. The underbrush is formed by *Ceanothus velutinus* of medium density, from 4 to 6 feet high, in a uniform cover.

On the two tracts near the lake white fir is mixed with yellow pine and Douglas fir, a little incense cedar, and a very little sugar pine. On the Otter & Burns tract the stand is composed of yellow pine and white fir, with occasional lodgepole pine.

On each tract conditions were more or less uniform, differences in elevation were negligible, and neither deep gulches nor steep slopes had to be figured with as disturbing factors. All in all, 160 trees were dissected and notes taken on all factors which possibly would have some bearing on the subject of this bulletin. In operating, the tracts were not clean cut; that is, not every white-fir tree in the area was felled and examined, since it was not the object of the study to establish a cull per cent for that particular region.

The data obtained are from selected trees. On the Pelican Bay Lumber Company's sales areas the trees, of course, had all been marked by the Forest Service officers in charge; on the Otter & Burns sales area some trees were marked, and others were felled independently of marking. On the Odessa ranger-station tract all trees examined were felled for our special purpose. The representation of trees of different ages, diameter, and height classes on the three tracts, therefore, is not expressed correctly by the number of trees examined on each tract.

LOCAL PATHOLOGY OF WHITE FIR.

The pathology of white fir in the Upper Klamath Lake region is comparatively simple. Of injurious factors of an inanimate nature, fire, lightning, and frost are common.

Very few species of fungi inhabiting living white fir are found on the three tracts. As we are mainly interested in the pathology of the wood, the occasional occurrence of *Peridermium elatinum* and of *Lophodermium nervisequium* becomes an entirely negligible factor.

Of heartwood-destroying fungi in living white fir, *Echinodontium tinctorium* is by far the most common, and sporophores are numerous. About 75 per cent of all cases of decay were due to this fungus. Occasionally decay may with some certainty be traced to *Fomes pinicola*. In one case a sporophore of an *Irpex* was found in the decayed hollow of the trunk. *Trametes pini* is missing altogether, though found occasionally on neighboring sugar pine. Decay caused by *Polyporus schweinitzii* was found in several cases, never with sporophores.

In other cases the decay was too indefinite to allow an identification of the fungus causing it. This is particularly true for the many cases of localized advance rot connected with scars from diffused lightning.

The preponderance of *Echinodontium tinctorium*, especially in connection with really damaging decay, is so marked that in this study all important cases of decay are considered to be caused by this fungus.

A study of the fungi destroying down timber lies beyond the scope of this bulletin. The only practical aspect of their activity lies in the fact that down timber, limbs, branches, twigs, and needles are decomposed very rapidly.

It is evident that all the points discussed in the preceding pages must be kept in mind in taking field notes. But this is not sufficient. Work of this kind has very much the character of an exploration; surprises and discoveries are possible at any point of the road, and it is therefore indispensable constantly to be on guard in order not to overlook any phenomenon worthy of observation.

TABULATION OF DATA.

The next step is proper tabulation of the data obtained. The three tracts were so close together and conditions so similar that they were considered as one, and all notes were combined. Separate interpretation of the notes of each tract showed differences only in detail. The procedure was as follows:

A first table was compiled from the field notes giving all important data as well as all such data which might have a bearing on the subject of this bulletin. As we are particularly interested in the problem of the relation of age to infection and subsequent decay, a second table gave the same notes arranged progressively by the ages of the trees examined. This table formed the basis for further operations.

The youngest tree dissected was 60 years old, and it is the first to show decay (Table I). The possible age limit of infection is therefore at least 60 years; it is probably lower. But in practical forestry we do not seek an answer to the question of the earliest age at which a tree might become infected, interesting as this is from a mycological point of view, but, rather, from what age may we with reasonable certainty assume that serious decay becomes so prevalent as to distinctly impair the merchantability of the timber.

The tree in question has a diameter breast high of 10.1 inches; it is 44 feet high. A healed-over broad scar still visible externally at 2 to 8 feet above ground corresponds to an internal scar, reaching from 2 to 10 feet, and was probably caused by lightning. The injury happened 22 years ago and was distinctly superficial; the deterioration, in the form of a slight discoloration of the sapwood, follows this scar only, without extending any farther into the wood. This superficial damage does not render the affected logs unmerchantable. For practical purposes, therefore, such cases may be disregarded; they are negligible. In the interpretation of our material, the character and the degree of the damage must be considered with special relation to their bearing on the merchantability of the lumber. Not only the extent in longitudinal direction but also the distribution of the decay over

the cross section enter into the valuation of this factor. In the present study, the lateral extent of decay, the distribution over the cross section, was estimated, as it is in practical scaling. Actual measurements are difficult to take, on account of the immense variability of the decay. In Table I, decay which neither in lateral extent nor in degree was considered sufficient to seriously injure the merchantability of the part affected was marked as negligible. The longitudinal decay was taken in linear feet, and the entire length was considered as affected, in order not to complicate the computation too much. We must distinguish between superficial decay of the sapwood and the more serious decay of the heartwood. Figures of superficial decay of sapwood are given in brackets (Table I, column 5).

The next trees are sound. A negligible decay occurs in a tree 73 years old. Its diameter breast high is 11.2 inches; its height 58 feet. The light decay started from an internal scar, caused by fire 23 years ago and healed over in 5 years, but it remained in close proximity to the scar without spreading. Again, a number of sound trees follow. Then the first more serious decay appears.

The tree in question is 84 years old, its diameter breast high only 8 inches, height only 45 feet. Both fire and lightning have played havoc with this individual. An open scar extends from the ground 21 feet up the bole. The tree is quite evidently not in good health, the sapwood is very narrow, and the crown is lopsided and very short. Even in this case the decay follows more or less the open scar, but it is sufficiently serious to cull the affected parts in so small a tree; in a larger and thriftier one the damage would be called more or less local and a nominal deduction made in the scale. From a lumbering point of view this tree may be disregarded.

So far, all trees considered had been either thrifty or not very seriously wounded. Here we have an obviously suppressed, unhealthy, and badly wounded tree; it presents at the same time the first case of decay that is not to be called negligible. The following trees are sound; then follows a negligible trace of decay in an 86-year-old tree, badly suppressed (diameter breast high 4 inches, height 13 feet), grown in dense shade, with a remarkably small crown and with a healed-over frost crack, but no other wounds. After several sound, fairly thrifty trees follows a tree 87 years old, badly suppressed (diameter breast high 7.8 inches, height 39 feet), with a very short crown, wounded badly by fire and lightning (open scar from ground to 18 feet), and with decay following more or less closely the open scar.

From these and the following trees, it appeared possible that with increasing age the crown class, or rather the degree of suppression and dominance, played a rôle with regard to the extent and seriousness of the decay. Preliminary studies on incense cedar had given the same indications. It seemed desirable, therefore, to express this degree of

suppression and dominance by a figure which would allow direct comparison between trees of the same age. Height alone would be misleading. Volume table figures can not be used, since they are based on sound normal trees. The relation of height to diameter breast high, expressed in total volume, was thought to be a safer index. The object being to obtain directly comparable figures by ages and not the exact volume, the tree was considered as a perfect cone over the stump, at which we had taken the ages. From somewhat scanty, but individually reliable notes, the diameters at the stump (diameter outside bark 18 inches) were obtained, and from these and the height the volume of the cone in cubic feet was computed.

TABLE I.—*Fundamental data on the pathology of the white fir.*

No. of tree.	Age.	Volume (cubic feet).			Character of wounds.
		For each tree.	Average for trees of same age.	Of rot, including advance rot (percentage of total volume).	
1	2	3	4	5	6
136.....	60	11.3	15(?)	¹ [34.2]	Lightning.
105.....	69	25.1	19	—	Leader healed in.
145.....	71	11.8	20	—	No wounds.
135.....	72	18.8	20	—	Very slight lightning.
147.....	72	7.7	20	—	No wounds.
143.....	73	18.5	20.3	12.7	Fire; healed.
159.....	76	23.0	21	—	Lightning.
111.....	78	12.4	21.3	—	Very little lightning.
134.....	80	31.4	23	—	Do.
139.....	81	45.5	24	—	Several scars.
138.....	82	29.9	24.1	—	Lightning (?).
89.....	84	44.4	24.6	—	No wounds.
125.....	84	8.9	24.6	82.8	Fire, open; lightning.
130.....	84	25.6	24.6	—	Little lightning.
133.....	85	7.5	25	—	No wounds.
137.....	86	33.7	26	—	Little lightning.
144.....	86	6.3	26	Negligible.	Frost ridge.
146.....	86	22.8	26	—	No wounds.
148.....	87	13.3	26.5	—	Lightning.
149.....	87	27.1	26.5	—	Very little lightning.
124.....	87	6.8	26.5	82	Lightning with fire.
129.....	87	9.6	26.5	—	Fire; healed.
88.....	90	30.1	29	19.9	Fire, healed; lightning.
90.....	92	128.1	30	—	No wounds.
128.....	92	10.2	30	—	Very little lightning.
103.....	94	44.8	31	—	Fire, open; lightning.
122.....	96	38.1	32.5	[4.53]	Fire, open.
127.....	96	32.9	32.5	—	No wounds.
76-a ²	96	25.1	32.5	55.3	Fire, open.
76-b ²	96	25.1	32.5	13.5	Lightning.
21.....	101	46.5	37	—	Do.
120.....	102	22.3	38	16.8	Fire, open.
132.....	103	34.2	39	61	Fire; lightning.
46.....	103	35.2	39	—	No wounds.
72-a.....	104	25.5	40	[2.39]	Lightning.
72-b.....	104	25.5	40	71.8	Do.
158.....	104	68.2	40	47.6	Old girdling; lightning.
126.....	105	20.7	41	43.5	Fire, open.
18.....	105	90.3	41	—	No wounds.
20.....	105	32.2	41	—	Do.
45.....	105	58	41	—	Do.
87.....	105	52	41	—	Do.
102.....	106	29	42	46.9	Fire, open.
121.....	106	48.3	42	Traces.	Lightning.
68.....	107	17.0	43	45.5	Falling tree.

¹ The use of brackets ([]) in column 5 indicates superficial decay of sapwood.² The letters a and b indicate two distinct foci of decay in the same tree.

TABLE I.—*Fundamental data on the pathology of the white fir—Continued.*

No. of tree.	Age.	Volume (cubic feet).			Character of wounds.
		For each tree.	Average for trees of same age.	Of rot, including advance rot (percentage of total volume).	
1	2	3	4	5	6
80.....	107	40.6	43	[92.2]	Lightning.
123.....	107	39.6	43	—	Little lightning.
19.....	107	65	43	—	No wounds.
44.....	107	55.0	43	[9.12]	Frost crack.
23.....	108	61.2	44	—	No wounds.
62.....	109	33.8	45	—	Do.
100.....	110	30.0	46	68.5	Fire, open.
22.....	110	47.7	46	—	No wounds.
75.....	110	14.7	46	—	Fire, open.
78.....	110	72.6	46	58.7	Do.
108.....	110	24.8	46	—	Little lightning.
110.....	110	26.8	46	—	Very little lightning.
104.....	111	32.1	47	23.7	Fire, open.
131.....	111	14.6	47	—	Fire; little lightning.
94.....	112	66.2	48	42.9	Twin healed in; frost crack.
99.....	112	40.8	48	42.1	Fire, open; lightning.
37.....	112	40.7	48	51.5	Frost crack.
96.....	113	25.7	49	[23.9]	Fire, open.
101.....	114	30.3	50	—	Fire; lightning.
97.....	116	11.7	52	[Trace.]	Fire, open.
109.....	116	36.3	52	40	Do.
98.....	118	11.5	53.5	—	No wounds.
140.....	118	20.5	53.5	—	(?)
40.....	119	89.5	54	—	Fire.
74.....	119	37.6	54	100	Fire; lightning.
115.....	121	18.9	56	—	Lightning.
150.....	122	46.3	57	—	Little lightning.
58.....	123	39.5	58	89.0	Frost crack.
69.....	123	18.5	58	[8.8]	Lightning.
154.....	123	21.8	58	77	Fire, open.
38.....	124	141	59	29.0	Fire.
56.....	124	21.3	59	60.0	Frost crack; lightning.
113.....	124	30.5	59	Negligible.	Fire, open; lightning.
33.....	125	53.5	61	—	Lightning.
41.....	125	125.5	61	58.1	Fire, open.
60.....	126	42.7	62	82.1	Frost crack.
79.....	129	85.6	65	80.3	Fire, open; frost crack.
54.....	130	32.8	66	77.5	Lightning.
63.....	130	52.3	66	32.4	Fire, open.
65.....	131	14.3	67	93.7	Frost crack.
17.....	132	87.4	69	—	No wounds.
30.....	132	256.5	69	—	Do.
49.....	132	98.2	69	65.3	Frost crack.
42.....	133	90.2	70	34.6	Fire, open.
112.....	133	26.4	70	—	Lightning.
53.....	134	28.8	71	21.8	Do.
28.....	135	55.1	73	42.0	No wounds.
55.....	135	83.2	73	60.7	Fire; frost cracks; lightning.
26.....	136	9.9	74	95.6	Frost crack.
16.....	136	108	74	—	No wounds.
48.....	136	86.4	74	76.9	Do.
1.....	137	49.1	76	—	Do.
50.....	137	33.6	76	85.3	Lightning.
2.....	138	77.4	78	—	Do.
15.....	138	76.3	78	—	Frost crack.
6.....	140	54.4	80	96.4	Fire.
7.....	140	187.0	80	—	No wounds.
50.....	140	20.6	80	132.7	Lightning.
119.....	140	24.3	80	100	Lightning, severe.
153.....	140	50.4	80	—	Lightning.
155.....	140	28.2	80	00	Fire, open; lightning.
43.....	140	136.5	80	133.5	Fire, open.
156.....	141	51.1	82	00	Do.
61.....	143	35.0	86	51.2	Falling tree; frost crack; lightning.
11.....	144	235.5	87	—	No wounds.
4.....	146	94.5	90	[27.7]	Fire.
106.....	146	30.0	90	88]	Frost crack; lightning.
5.....	148	135.5	94	70	Frost crack.
35.....	148	154	94	—	No wounds.
92.....	149	34.1	96	60.1	Fire, open.
10.....	150	66.5	97	—	No wounds.

TABLE I.—*Fundamental data on the pathology of the white fir—Continued.*

No. of tree.	Age.	Volume (cubic feet).			Character of wounds.
		For each tree.	Average for trees of same age.	Of rot, including advance rot (percentage of total volume).	
1	2	3	4	5	6
25.....	150	123.5	97	81.5	Frost crack.
114.....	150	45.6	97	55.5	Fire, open; lightning.
157.....	150	112.5	97	68	Do.
151.....	151	16.6	99	41.3	(?)
85.....	152	192.5	101	58.1	Frost crack.
9.....	152	75	101	15.7	Do.
13.....	155	235	107	63.2	Fire, open.
51.....	155	121	107	36.2	Do.
117.....	155	37.7	107	Negligible.	Lightning.
83.....	156	380	109	36.5	Fire; frost crack.
91.....	156	96.5	109	32.8	Do.
27.....	159	152.0	109	—	No wounds.
12.....	160	224.5	116	73.7	Fire, open.
93.....	160	26.8	116	98.5	Fire, open; lightning.
118.....	161	68.6	118	—	Lightning.
160.....	161	68.2	118	89.4	Frost crack.
116.....	162	38	121	—	Lightning.
47.....	163	122.5	123	—	Notes missing.
81.....	163	106	123	82.9	Fire, open.
84.....	164	417	125	25.5	Frost crack (healed); lightning.
3.....	165	(?)	127	Incomplete.	Fire, open.
51.....	165	128.5	127	53.4	Fire; lightning.
24.....	166	57.2	129	(?)	Notes missing.
32.....	166	171.5	129	—	No wounds.
29.....	168	179	134	—	Fire.
82.....	169	291.7	136	6.8	Fire; frost cracks.
8.....	170	328.5	138	53	Fire.
57.....	170	121	138	87.4	Frost crack.
67.....	170	123.8	138	67.2	No wounds.
64-a.....	175	68.0	150	47.1	Fire, open.
64-b.....	175	68.0	150	16.4	Lightning.
36.....	178	212.7	158	—	Frost crack.
52.....	178	127.7	158	[5.1]	Lightning.
77.....	180	133	164	16.7	Fire, open.
71.....	183	100	[166]	39.5	Lightning.
34.....	185	148.3	[166]	—	No wounds.
95.....	185	100.5	[166]	53.6	Fire, open.
107.....	186	42.85	[166]	—	Lightning.
66.....	189	64.4	[168]	—	Frost ridge; lightning.
39.....	191	546	[168]	52	Fire.
86.....	192	110.7	[170]	95.5	Fire, open; frost cracks.
14.....	200	115.7	[180]	Negligible.	Frost crack.
142.....	200	26.0	[180]	100	Fire, open; lightning.
73.....	221	196	[190]	100	Frost crack; lightning.
59.....	232	235	[200]	71.3	Lightning.
141.....	258	46.7	[220]	[100]	Fire, open; frost cracks; lightning.

These volumes are, of course, not directly comparable with each other; they have a meaning only when individually compared with normal volumes for the same age. It was necessary, therefore, to curve data collected on normal trees, such as were selected for volume tables in larger numbers on the same area. The most reliable portion of this curve lies between 80 and 180 years. The relation of the actual to the average volume of trees of the same age we may use as an index of suppression or dominance of the individuals in question.

The volume of the decayed part of the bole was figured as the affected part of the cone. But instead of giving the decay simply in

cubic feet, making constant reference to the total volume of the tree necessary, the volume of the rot was expressed in percentage of the total volume. Advance rot—that part of the wood already under the influence of the mycelium—is included. It must be kept in mind that all figures given under this heading (column 5) are therefore likely to be high. To be on the conservative side, all measures of decay were taken very carefully, and in all cases where there was any possible doubt the uncertain part was measured as decay. But since the same procedure was followed consistently the results are directly comparable.

Table I gives us our working material in figures. Column 1 shows the individual number of each tree from the field notes and is given only for convenience of reference, the trees being arranged in the order of their ages (column 2). Column 3 shows the actual or total volume in cubic feet of each tree, considered as a perfect cone. Column 4 gives the volume in cubic feet for the average tree of the same age. Column 5 shows the volume of rot (including advance rot) in cubic feet expressed as a percentage of the total volume of the tree. Column 6 shows the character of the wounds.

CONDENSATION OF DATA.

It proved difficult to interpret intelligently this mass of figures. If there existed any relation between decay and possible influencing factors, it certainly did not appear very clearly from this table. It became necessary to simplify and condense the material.

Instead of expressing dominance or suppression by the relation of the actual to the normal volume in figures, the system of crosses described above for the field notes was used. Three classes were adopted—dominant, intermediate, and suppressed. Those volumes which came closest to the average were considered intermediate and entered in the table with one cross, which expresses the affirmative; a dash signifies negation. In the intermediate class therefore there can be not more than one cross. The deviation from this average shows in the two other classes, and as here all degrees are possible, the degree of suppression or of dominance is shown with one, two, or three crosses. Thus, three crosses under “Dominance” mean that the tree is as far beyond the average as is possible in that locality. On the other hand, one cross under “Suppression” means that the tree is decidedly suppressed, two crosses that it is badly suppressed, and three crosses indicate the highest degree of suppression. This classification is admittedly arbitrary; it seemed to answer the purpose, however, and has so many advantages, with its possible grades and its graphical clearness, that it may be retained until some better method is devised. (Table II, columns 3, 4, and 5.)

To reduce the figures in column 5 of Table I to simpler symbols was more difficult. Here the entire affected part of the cone for practical purposes was considered as cull, including the sapwood. In reality, there are, of course, all gradations from a slight discoloration of the sapwood following a long lightning scar or a number of smaller scars to complete destruction of the heartwood by decay. In order to simplify this column and to bring out more forcibly its relation to influencing factors, the writer tried to reduce the percentage figures to ratings, applying the system of crosses used throughout this study, taking into account not only the volume percentage of rot in cubic feet, but also the character of the injury with regard to the degree of rottenness. Thus, one cross in parentheses, (x), signifies slight and negligible local discoloration; one cross (not in parentheses) shows distinct rot, but affecting not more than about one-third of the tree; two crosses, about two-thirds of tree affected; three crosses, more or less of the entire tree affected. In each case, the character of the decay as indicated by the detailed field notes was given due consideration. This explains apparent discrepancies between decay rating and decay volume in the percentages in Table I, where the affected part of the bole was considered as cull for the entire length of the decay. In decay rating, the actual loss in merchantability was expressed according to the character of the rot and its extent. This valuation of the decay, it is true, is necessarily somewhat arbitrary. It is really the condensation of carefully taken field notes and measurements and must serve until a more satisfactory method can be found. Where general relationships only are concerned, as in this case, our symbols may be sufficiently correct, provided they are based on exact figures and reliable field notes. (Table II, column 6.)

In order to insure a higher degree of reliability for the decay-rating symbols, the operation was repeated some time later without consulting the results of the first. With insignificant exceptions, both ratings were identical.

In much the same way the character and degree of wounding was reduced to a system of crosses. Plainly, this can be done only from field notes, which were generally amplified by actual measurements of the size and extent of the wound. The chances of inoculation offered by a wound decide its rating. That deep wounds, particularly such as have remained open for a longer time, are rated higher than small superficial injuries, soon healed over, is self-evident. The system of crosses is the same as heretofore explained. (Table II, column 7.)

The next column (Table II, column 8) indicates the means whereby the fungus entered the tree, as evidenced by the analysis.

TABLE II.—Condensed data on the pathology of the white fir.

No. of tree.	Age.	Degree of dominance or of suppression.			Decay rating.	Wound rating.	Infection traced to—	Apparent condition of crown.	Remarks.
		Dominance.	Intermediate.	Suppression.					
1	2	3	4	5	6	7	8	9	10
136	60	—	—	x	—	xx	Lightning.....	(x)	Negligible; advance rot.
105	69	xx	—	—	—	(x)	—	(x)	
145	71	—	—	xx	—	—	—	(x)	Negligible.
135	72	—	—	x	—	—	—	(x)	
147	72	—	—	xx	—	—	—	(x)	
143	73	—	—	x	—	xx	Fire.....	(x)	
159	76	—	x	—	—	x	—	x	
111	78	—	—	xx	—	—	—	x	
134	80	xx	—	—	—	—	—	(x)	
139	81	xxx	—	—	—	xx	—	(x)	
138	82	xx	—	—	—	x	—	(x)	
89	84	xxx	—	—	—	—	—	x	
125	84	—	—	xxx	xx	xxx	Fire; lightning.	xxx	Advance rot.
130	84	—	x	—	—	—	—	(x)	
133	85	—	—	xxx	—	—	—	x	
137	86	x	—	—	—	x	—	(x)	
144	86	—	—	xxx	—	xx	Frost crack.....	xxx	
146	86	—	—	x	—	—	—	(x)	
148	87	—	—	xx	—	xx	—	(x)	
149	87	—	x	—	—	—	—	(x)	
124	87	—	—	xxx	x	xxx	Lightning; fire.	xxx	
129	87	—	—	xxx	—	x	—	x	
88	90	—	x	—	x	xx	Fire.....	x	Advance rot.
90	92	xxx	—	—	—	—	—	x	
128	92	—	—	xx	—	—	—	(x)	Negligible.
103	94	x	—	—	—	xx	—	x	
122	96	x	—	—	—	xx	Fire, open.....	x	Advance rot.
127	96	—	x	—	—	—	—	x	
76-a	96	—	—	xx	xx	xxx	Fire, open.....	x	Advance rot.
76-b	96	—	—	xx	x	xxx	Lightning.....	x	
21	101	xx	—	—	—	xx	—	x	Advance rot.
120	102	—	—	xx	—	xxx	Fire, open.....	x	
132	103	—	—	x	xx	xxx	Fire.....	(x)	Open 22 years.
46	103	—	—	x	—	—	—	x	
72-a	104	—	—	xx	—	xxx	Lightning.....	xx	Advance rot.
72-b	104	—	—	xx	x	xxx	do.....	xx	
158	104	xx	—	—	xx	xxx	Girdling.....	(x)	Almost completely girdled 82 years ago; wound open 31 years; mostly advance rot.
126	105	—	—	xx	xx	xxx	Fire, open.....	x	
18	105	xxx	—	—	—	—	—	x	
20	105	—	—	xx	—	—	—	x	
45	105	x	—	—	—	—	—	x	
87	105	x	—	—	—	—	—	x	
102	106	—	—	xxx	xx	xxx	Fire, open.....	xx	
121	106	—	x	—	—	xxx	Lightning.....	x	
68	107	—	—	xxx	x	xxx	Falling tree.....	xx	
80	107	—	x	—	x	xx	Lightning.....	x	
123	107	—	—	x	—	—	—	x	Advance rot. local-ized in scars.
19	107	xx	—	—	—	—	—	x	
44	107	xx	—	—	—	xx	Frost crack.....	(?)	Negligible.
23	108	xx	—	—	—	—	—	x	
62	109	—	—	x	—	—	—	x	Mostly advance rot.
100	110	—	—	xx	x	xxx	Fire, open.....	x	
22	110	—	x	—	—	—	—	x	
75	110	—	—	xxx	—	xx	—	x	
78	110	xx	—	—	xx	xxx	Fire, open.....	(x)	
108	110	—	—	xxx	—	—	—	(x)	Rot following two very long open scars.
119	110	—	—	xxx	—	—	—	(x)	
104	111	—	—	xx	x	xxx	Fire, open.....	x	Advance rot.
131	111	—	—	xxx	—	x	—	(x)	
94	112	x	—	—	x	xxx	Twin and frost crack.	x	Very slight advance rot.
39	112	—	—	x	x	xxx	Lightning.....	xx	
37	112	—	—	x	x	xxx	Frost crack.....	x	Slight advance rot.
96	113	—	—	xx	—	xxx	Fire, open.....	x	
101	114	—	—	xx	—	x	—	x	Little typical rot.

TABLE II.—Condensed data on the pathology of the white fir—Continued.

No. of tree.	Age.	Degree of dominance or of suppression.			Decay rating.	Wound rating.	Infection traced to—	Apparent condition of crown.	Remarks.
		Dominance.	Intermediate.	Suppression.					
1	2	3	4	5	6	7	8	9	10
97	116	—	—	xxx	—	xx	Fire.....	x	Negligible.
109	116	—	—	xx	x	xx	Fire, open.....	x	Mostly advance rot.
98	118	—	—	xxx	—	—	—	x	—
140	118	—	—	xxx	—	(x)	—	(x)	—
40	119	xx	—	—	—	xx	—	x	—
74	119	—	—	xx	x	xxx	Fire (?), with lightning.	x (?)	Advance rot.
115	121	—	—	xxx	—	x	—	x	—
150	122	—	—	x	—	—	—	(x)	—
58	123	—	—	xx	xx	xx	Frost crack.....	x	Much advance rot.
69	123	—	—	xxx	—	x	Lightning.....	x	Advance rot; negligible.
154	123	—	—	xxx	xx	xxx	Fire, open.....	x	Very long scar.
38	124	xxx	—	—	x	xx	Fire.....	x	Little advance rot.
56	124	—	—	xxx	x	xx	Frost crack.....	x	Advance rot.
113	124	—	—	xx	—	xx	Fire; lightning..	x	—
33	125	—	—	x	—	—	—	x	—
41	125	xxx	—	—	xx	xxx	Fire, open.....	x	Much advance rot.
60	126	—	—	xx	xxx	xx	Frost crack.....	x	Sporophore.
79	129	x	—	—	xxx	xxx	Fire, with frost crack.	x	Two very bad burns held open by frost crack for 85 years; sporophore.
54	130	—	—	xxx	xx	xxx	Lightning.....	x	Much advance rot; young sporophore.
63	130	—	—	xx	xx	xxx	Fire, open.....	xx	Very bad open fire scar.
65	131	—	—	xxx	xxx	xx	Frost crack.....	(?)	—
17	132	xx	—	—	—	—	—	x	—
30	132	xxx	—	—	—	—	—	x	—
49	132	xx	—	—	xxx	xx	Frost crack.....	x	Much advance rot; 2 sporophores.
42	133	xx	—	—	x	xxx	Fire, open.....	x	Mostly advance rot.
112	133	—	—	xxx	—	xx	—	xx	—
53	134	—	—	xxx	x	x	Twin (?).....	x	Advance rot.
28	135	—	—	xx	x	—	Knots.....	x	Slight advance rot.
55	135	x	—	—	xx	xxx	Fire, with frost crack.	x	Much advance rot.
26	136	—	—	xxx	xxx	xx	Frost crack.....	xxx	Sporophore.
16	136	xx	—	—	—	—	—	x	—
48	136	—	x	—	xxx	—	Knots.....	x	Sporophore.
1	137	—	—	xx	—	—	—	x	—
50	137	—	—	xxx	xxx	x	Lightning and knots.	x	Much advance rot.
2	138	—	x	—	—	xx	—	x (?)	—
15	138	—	—	—	—	x	—	x	—
6	140	—	x	xxx	xxx	xx	Fire.....	(?)	Sporophore.
7	140	xxx	—	—	—	—	—	x	—
70	140	—	—	xxx	x	xxx	Lightning.....	x	Slight advance rot.
119	140	—	—	xxx	xxx	xxx	do.....	xxx	—
153	140	—	—	xx	—	x	—	(x)	—
155	140	—	—	xxx	xxx	xxx	Fire, open.....	xxx	—
43	140	xx	—	—	x	xxx	do.....	x	Tree almost killed at age of 81 years; mostly advance rot.
156	141	—	—	xxx	xxx	xxx	do.....	x	—
61	143	—	—	xxx	xx	xx	Frost crack; wounds from falling tree.	x	Much advance rot near wounds.
11	144	xxx	—	—	—	—	—	x	—
4	146	—	x	—	x	xx	Fire.....	x	Advance rot.
106	146	—	—	xxx	xx	xxx	Lightning and frost.	x	Much advance rot in scars.
5	148	xx	—	—	xx	xx	Frost crack.....	x	Small sporophore.
35	148	xxx	—	—	—	—	—	x	—
92	149	—	—	xxx	xx	xxx	Fire, open.....	xx	Rot following scars.
10	150	—	—	xx	—	—	—	x	—
25	150	xx	—	—	xxx	xxx	Frost crack.....	x	—
114	150	—	—	xxx	xx	xxx	Fire, open.....	x	—
157	150	x	—	—	xx	xxx	do.....	xx	—
151	151	—	—	xxx	xx	xx	(?)	xx	Much advance rot; small tree.

TABLE II.—Condensed data on the pathology of the white fir—Continued.

No. of tree.	Age.	Degree of dominance or of suppression.			Decay rating.	Wound rating.	Infection traced to—	Apparent condition of crown.	Remarks.
		Dominance.	Intermediate.	Suppression.					
1	2	3	4	5	6	7	8	9	10
85	152	xx	—	—	xx	x	Frost crack.....	x	Two sporophores.
9	152	—	—	xx	x	xx	do.....	x	Scar long healed over.
13	155	—	—	xxx	xx	xxx	Fire, open.....	x	
31	155	x	—	—	x	xxx	Fire.....	x	Slight advance rot.
117	155	—	—	xxx	—	xx	Lightning.....	xxx	
83	156	xxx	—	—	xx	xxx	Frost crack.....	x	Much advance rot and shake.
91	156	—	—	x	x	xxx	Fire, open.....	xx	
27	159	xxx	—	—	—	—	—	x	
12	160	xxx	—	—	xxx	xxx	Fire.....	x	
93	160	—	—	xxx	xxx	xxx	Fire, open.....	x	
118	161	—	—	xxx	—	x	—	xxx	
160	161	—	—	xxx	xxx	xxx	Frost crack.....	xxx	Sporophore.
116	162	—	—	xxx	—	x	—	x	
47	163	—	x	—	—	—	—	x	
81	163	—	—	x	xxx	xxx	Fire, open.....	xxx	
84	164	xxx	—	—	xx	xx	Knots.....	x	Small sporophore.
3	165	(?)	(?)	(?)	xx	xxx	Fire.....	x	Notes incomplete; D. B. H. 26.5 inches.
51	165	—	x	—	xx	xx	do.....	x	Much advance rot.
24	166	—	—	xxx	x	(?)	(?)	x	Notes incomplete.
32	166	xx	—	—	—	—	—	x	
29	168	xx	—	—	—	(x)	—	x	
82	169	xxx	—	—	x	xxx	Knot.....	(x)	Very thrifty.
8	170	xxx	—	—	xx	xx	Fire.....	x(?)	
57	170	—	—	—	x	xxx	Frost crack.....	xx	Five sporophores.
67	170	—	—	—	x	xxx	Knot.....	x	Small sporophores.
64-a	175	—	—	xxx	xxx	xxx	Fire, open.....	x	
64-b	175	—	—	xxx	xx	xxx	Lightning.....	x	Advance rot; small tree.
36	178	xx	—	—	—	x	—	x	
52	178	—	—	x	—	x	Lightning.....	x	Advance rot.
77	180	—	—	xx	x	xxx	Fire.....	x	Advance rot and shake.
71	183	—	—	xx	x	xxx	Lightning.....	xx	Advance rot.
34	185	—	—	x	—	—	—	x	
95	185	—	—	xx	xx	xxx	Fire, open.....	x	
107	186	—	—	xxx	—	xx	—	x	
66	189	—	—	xxx	—	xx	—	x	
39	191	xxx	—	—	xx	xxx	Fire.....	x	Fire 110 years ago.
86	192	—	—	xx	xxx	xxx	Frost crack.....	x	Large sporophore.
14	200	—	—	xx	—	x	do.....	xxx	
142	200	—	—	xxx	xxx	xxx	Fire.....	xxx	Much advance rot; small tree.
73	221	—	x	—	xxx	xx	Frost crack with lightning.	xx	Four sporophores.
59	232	x	—	—	xxx	x	Lightning.....	(?)	Much advance rot.
141	238	—	—	xxx	xxx	xxx	Fire with frost crack.	xxx	Mostly advance rot with shake.

Another column concerns the apparent condition of the tree (Table II, column 9) and indicates the appearance of health of the crown, taking the healthy, thrifty tree as normal (indicated by one cross) and marking the degree of deviation from the normal in the usual way. Thus, one cross in parentheses, (x), means that the tree is an exceptionally healthy one; two crosses (not in parentheses) indicate that the crown is rather poor, either in development or that the color is abnormal, etc.; and a tree having a very much underdeveloped and sickly looking crown is marked with three crosses. The personal

factor may, of course, lead to misinterpretations unless the same standard is applied throughout the entire study. For this very reason it seemed doubtful from the beginning whether these data would be of much value. They are given here merely for the sake of completeness.

The condensed material was again tabulated. In the condensed table (Table II) the relation of decay to age can easily be followed by comparing columns 2 and 6. "Decay rating" is placed between "Suppression" and "Wound rating" in order to bring out forcibly any possible relation between these factors.

INTERPRETATION.

The column that interests us most is apparently the sixth, "Decay rating." In glancing over this column and comparing it with the neighboring ones we can read directly the connection of decay with factors that may be of influence. Each separate case of decay, of which one, two, or even more can occur on the same tree, may be called, for simplicity's sake, in this study, a "cull case." Each cull case is the result of a separate infection. The actual loss of timber by fire burning out the stump does not concern us here; cull from this source is included in the "volume of rot" whenever the decay is directly traceable to the fire wound. Otherwise the cull from fire is neglected. Cull from knots, limbs, or wind-shake is not considered. Altogether there are 97 cull cases.

The first two cull cases are negligible for practical purposes. Some loss occurs in tree No. 125, 84 years old. We see that this is a very badly suppressed tree, very seriously wounded, in very bad health, and that it is injured by both fire and lightning. Another case occurs in tree No. 124, age 87 years. Again suppression, wounding, and condition of health are marked with three crosses, indicating the worst possible conditions, together with two causes of wounds—fire and lightning. In both cases fire is the more serious, lightning often occurring higher up on the tree in numerous small wounds. It carries advance decay to the upper part of the bole and materially increases the volume-rot figure and the decay rating. The next cull case is a slight one (tree No. 88, age 90 years). The tree is intermediate, wound rating medium, health good, the decay only advance rot. Continuing down the "Decay-rating" column and comparing the symbols with those in the neighboring columns, we find that in almost every case the rating of rot more or less expresses or is explained by the factors of suppression and wound rating. Apparent discrepancies generally find their explanation under "Remarks" (column 10).

Suppression shows at an early age. A distinct preponderance of suppression is noticeable from about the age of 84 years. The first

very pronounced cases appear in the same year. They seem to become particularly common from about 110 to 120 years.

Suppression stands out strongly as an important factor. Out of the total of 97 cull cases, 66 are connected with suppression. Considering that our average volumes over ages were curved from figures which were rather low and that the intermediate white firs in a virgin uneven-aged mixed stand are rather to be considered as recovering suppressed trees than as dominants decreasing in rate of height growth the intermediate class may consistently be added to the suppressed, giving 73 in all, or about 75 per cent. Suppression is commonly connected with a more or less high decay rating, provided the tree is wounded seriously. Again, low-volume trees with marked decay are more liable to be a total loss on account of their form. A rot volume percentage of 50, for instance, leaves still a good deal of merchantable stuff in a tree with high volume, but it would make a small tree completely unmerchantable. In the comparatively few cases where dominant trees show decay, the wounding is either of very momentous character or the decay is more or less insignificant and localized near the scars. This is true at least for the younger trees.

In glancing over the decay column we see that the higher ratings, xx and xxx, begin rather suddenly to become more frequent after the trees have reached the age of about 123 to 126 years; after the age of about 129 or 130 years they become very common. While decay in the broadest sense of the word may show in trees 60 years old and perhaps younger, the critical age of white fir with regard to more serious decay appears to lie at about 130 years, at least for the region investigated, taking into account that we have to deal here with a practically virgin stand grown up under the cumulative risk from suppression, frost, lightning, and the other factors of influence. Decay of any consequence appears at this age in trees with a combination of wounding and suppression. In the few apparent exceptions the decay is localized near unusually large wounds.

We find, further, that up to about 150 (148) years in badly wounded but dominant thrifty trees the decay is either not very far advanced in degree, if in extent, or that the wounding is of quite extraordinarily severe character.

Tree No. 49, age 132, seems to form an exception, but we will see later that frost cracks, though not offering a large opening by virtue of their length, are instrumental in the longitudinal advance of the decay. It seems that after about 150 years thriftiness as expressed by dominance is less able to outbalance the influence of serious wounding.

If it is at all permissible to draw any inference from the comparatively small amount of material at hand, we may distinguish three critical stages in the life history of wounded white-fir trees, and we

must remember that by far the greater number of our trees, especially after they have reached the age of about 80 to 90 years, are wounded.

The first is the "age of infection," which may be at 60 years or below. Here the infection rarely leads to more than negligible decay unless the tree is handicapped by quite unusually severe conditions, such as very large old wounds.

The second, at about 130 years, which we may term the "critical age," marks the point after which a combination of pronounced suppression and heavy wounding generally results in distinct decay. This combination of deleterious factors is one commonly found in virgin forests. Wounding alone is not sufficient to unfavorably counteract thriftiness of growth.

Another change comes about at 150 years, when even dominant (that is, thrifty) trees become subject to extensive and intensive decay. We might term this the "age of decline," because the inability of the individual to throw off or keep in check the growth of the wound parasite in its heartwood indicates a distinct decrease in resistive powers, whatever their specific action may be, induced by age. For thrifty but wounded white fir, such as we may expect to raise under management, the age of decline is, therefore, the factor which will influence the rotation and cutting cycles of the species, since for many years to come the risk of inoculation will be more or less the same. There will be fires as long as there are lightning storms. Wounding through lightning and frost are inevitable. Besides, many trees are already wounded.

It is of interest to note that of a total of 160 trees only about 25 per cent did not show any wounds except very slight lightning scars. All the rest were wounded from some cause or other. Often a combination of fire, lightning, and frost cracks results in scarring a tree to such an extent that almost in every foot some blemish will be found. This is particularly true of the older trees which have been exposed to the cumulative risk of many years. Any of these wounds, if large enough, may offer an entrance to fungi. After the trees have reached the age of about 80 to 90 years, more than 70 per cent of them are already more or less badly wounded and therefore exposed to inoculation. After they are about 106 years of age more than 80 per cent are wounded.

In the remote future, when all these wounded trees are removed and when the risk of wounding for the trees growing up meantime is minimized, a new age of decline may be established. What this age of decline might be for unwounded white fir in managed forests we can not tell from our material, because of 97 cases of decay only 6 were not to be traced to some wounding. It is obviously out of the question to take even a clue from data of so scanty a nature. It may simply be mentioned that the first case of this kind appears at

an age of 134 years in a suppressed tree. After all, it may be more than a coincidence that the first case of such infection in a suppressed tree occurs near the critical age for suppressed white firs in this region. It is within reason to assume that thrifty, uninjured white firs run only the evidently not very great risk of becoming infected through branch stubs. But decay entering through knots is always caused by fungi of a very aggressive character, such as *Echinodontium tinctorium*, which is not always the case with wounds. As a possible cause of infection we may also mention dead and broken-off leaders or volunteers, the stubs of which are only slowly overgrown.

It would appear that, if infections of unwounded trees are really so rare, white fir will take care of itself on the managed areas of the future. This would probably be the case in an ideal, 100 per cent normal forest. But this is utopian. There will always be a certain risk of wounding. Even after the already wounded individuals are eliminated, which will consume a number of decades, it is unreasonable to expect that our forests should then be so much closer to the normal than the best kept European forests are at the present day. How severe the loss from *Trametes pini* is in the Prussian forests has already been shown. Whatever may be the final verdict as to the age of decline of unwounded thrifty trees in managed forests, it can not be of more than purely theoretical interest to us and the next following generations. We must cope with present-day conditions as we find them, not as we would wish to have them.

The immense importance of fire in connection with decay appears so plainly from Table II that it is hardly necessary to emphasize the fact. The field notes show that in 59 trees wounded by fire, in only 11 was no decay traced to the fire wound. Fire, then, is one of the most important factors in connection with decay; all the more so, as fire generally attacks the butt part of the tree, and decay starting from fire wounds therefore destroys a much greater part of valuable timber than decay in the upper part of the bole.

Lightning generally results in comparatively light advance rot. From Table II it appears that the only tree in which serious decay could be traced to lightning, and in which it was neither connected with suppression nor with a serious wound from another source, is No. 59, 232 years old. To judge from our data, lightning is rarely connected with typical decay, although it often renders large parts of the tree partly unmerchantable.

The cumulative risk of wounding is shown in Table II (column 7) by the fact that the cases rated with three crosses become far more frequent after the trees have reached the age of about 90 to 100 years. After they have reached about that age such cases are commonly accompanied by decay. Serious decay follows serious wounding after

about the age of 130 years (critical age) when combined with pronounced suppression, and without this it follows after the age of about 150 years is reached. The risk of wounding increases naturally with the age of the tree.

A number of wounded and badly suppressed trees escape infection, although they are far beyond the critical age. Not every wound must necessarily be inoculated. All such cases found are compiled in Table III.

TABLE III.—Data on suppressed and wounded but not infected white-fir trees.

Age.	Suppression rating.	Wound rating.	Character of wound.	Age.	Suppression rating.	Wound rating.	Character of wound.
87.....	xxx	x	Fire.	140.....	xx	x	Lightning.
110.....	xxx	xx	Do.	161.....	xxx	x	Do.
111.....	xxx	x	Do.	162.....	xxx	x	Do.
121.....	xxx	x	Lightning.	186.....	xxx	xx	Do.
133.....	xxx	xx	Do.	189.....	xxx	xx	Do.

In all cases but one in Table III the degree of suppression is very high; in this case the wound rating is low. The dangerous fire wounds in this table are confined to the youngest ages, 87 to 111 years; they were comparatively small in each case. The rest of the wounds are all due to lightning, which, as will be remembered, does not open up the interior of the tree unless very large parts of the bark are killed. For inoculation and infection, the character of the wound is all important. Suppression has nothing to do with inoculation; only after infection has taken place does its influence make itself felt.

The characteristics of each of the three ages, of course, hold good through the following ages. The combination of wounding with suppression, as shown in the critical age, for instance, must continue to favor decay in the age of decline.

Relative thriftiness (apparent condition of the tree) seems to have the least influence on the decay factor. It is really nothing but a statement of the present temporary appearance of the individual tree, which may be entirely different from what it was a few years ago or what it will be in the near future.

That far-reaching decay must not necessarily be reflected in the appearance and increment of the tree is shown, for instance, by trees Nos. 25 (age 150), 157 (age 150), 85 (age 152), 83 (age 156), and others in Table II. In all the trees mentioned, *Echinodontium tinctorium* had established itself and was vigorously growing. Tree No. 85 (age 152) even had two sporophores, and more than half the volume of the tree was decayed, indicating that the fungus must have lived in the tree for many years. The tree was apparently very thrifty; its volume, 192.5 cubic feet, as against 101, the average for its

age (152 years). The increment was good. We can not, therefore, make *Echinodontium tinctorium* responsible for the decrease in thriftiness of infected white fir.

In order to further fix the relation between the character of the opening through which the fungus gains entrance into the wood and the character and extent of the decay, all cull cases were tabulated separately (Table IV).

TABLE IV.—Cull cases of white fir, showing the extent of typical rot and its relation to the wound through which the infection took place.

No.	Age.	Infection traced to—	Wounds.		Typical rot.		Remarks.
			Open.	In- ternal (healed over).	Confined to neigh- borhood of wounds.	Extend- ing much beyond wounds.	
1	2	3	4	5	6	7	8
136	60	Lightning.....	—	x	x	—	Negligible.
143	73	Fire.....	—	x	x	—	
125	84	Fire with lightning.....	x	—	x	—	
144	86	Frost crack.....	—	x	x	—	Negligible.
124	87	Lightning with fire.....	x	—	x	—	Advance rot.
88	90	Fire.....	—	x	x	—	
122	96	do.....	x	—	x	—	
76a	96	do.....	x	—	—	(x)	
76b	96	Lightning.....	x	—	—	—	Advance rot.
120	102	Fire.....	x	—	x	—	
132	103	do.....	—	x	—	(x)	Remained open 22 years.
72a	104	Lightning.....	—	x	x	—	
72b	104	do.....	—	x	x	—	
158	104	Girdling.....	—	x	x	—	Almost completely girdled 82 years ago; open 31 years.
126	105	Fire.....	x	—	x	—	
102	106	do.....	x	—	x	—	
121	106	Lightning.....	x	x	x	—	Negligible.
68	107	Wound from falling tree.....	x	—	x	—	
80	107	Lightning.....	—	x	x	—	
44	107	Frost crack.....	x	—	x	—	
100	110	Fire.....	x	—	x	—	
78	110	do.....	x	—	x	—	
104	111	do.....	x	—	x	—	
94	112	Twin and frost crack.....	—	x	x	—	
99	112	Lightning.....	—	x	x	—	
37	112	Frost crack.....	—	x	(?)	—	Frost.
96	113	Fire.....	x	—	x	—	
97	116	do.....	x	—	x	—	
109	116	do.....	x	—	x	—	
74a	119	Fire (?).....	—	x	x	—	
74b	119	Lightning.....	x	—	x	—	
58	123	Frost crack.....	—	x	—	x	Frost.
69	123	Lightning.....	—	x	x	—	
154	123	Fire.....	x	—	x	—	
38	124	do.....	—	x	x	—	
56	124	Frost crack.....	x	—	—	—	Advance rot.
113	124	Fire with lightning.....	x	—	x	—	
41	125	Fire.....	x	—	x	—	
60	126	Frost crack.....	—	x	—	x	Frost.
79	129	Fire with frost crack.....	x	—	—	x	Do.
54	130	Lightning.....	—	x	x	—	
63	130	Fire.....	x	—	x	—	
65	131	Frost crack.....	—	x	—	x	Frost.
49	132	do.....	—	x	—	x	Do.
42	133	Fire.....	x	—	x	—	
53	134	Twin (?).....	—	(?)	x	—	
28	135	Knots.....	—	—	—	x	Knots.
55	135	Fire with frost crack.....	—	x	—	x	Frost.
26	136	Frost crack.....	x	—	—	x	Do.
48	136	Knots.....	—	—	—	x	Knots(?).
50	137	Lightning and knots.....	—	x	—	x	Much advance rot.
6	140	Fire.....	(?)	(?)	—	x	Sporophore.
70	140	Lightning.....	—	x	x	—	
119	140	do.....	x	—	x	—	

TABLE IV.—*Cull cases of white fir, showing the extent of typical rot and its relation to the wound through which the infection took place—Continued.*

No.	Age.	Infection traced to—	Wounds.		Typical rot.		Remarks.
			Open.	In- ternal (healed over).	Confined to neigh- borhood of wounds.	Extend- ing much beyond wounds.	
1	2	3	4	5	6	7	8
155	140	Fire.....	x	—	—	x	Condition very poor; sup- pression xxx.
43	140	do.....	x	—	x	—	
156	141	do.....	x	—	x	—	
61a	143	Frost crack.....	—	x	—	x	Frost.
61b	143	Falling tree.....	—	x	x	—	Advance rot.
4	146	Fire.....	(?)	(?)	(?)	(?)	Notes incomplete.
106	146	Lightning and frost.....	x	—	x	—	Advance rot.
5	148	Frost crack.....	—	x	—	x	Frost.
92	149	Fire.....	x	—	x	—	
25	150	Frost crack.....	x	—	—	x	Frost.
114	150	Fire.....	x	—	—	x	Butt open from fire 73 years ago; suppression xxx.
157	150	do.....	x	—	x	—	
151	151	(?).....	—	x	x	—	
85	152	Frost crack.....	—	x	—	x	Frost.
9	152	do.....	—	x	x	—	
13	155	Fire.....	x	—	—	x	
31	155	do.....	x	—	x	—	
117	155	Lightning.....	—	x	x	—	
83	156	Frost crack.....	—	x	—	x	Frost.
91	156	Fire.....	x	—	x	—	
12	160	do.....	x	—	—	x	
93	160	do.....	x	—	—	x	Suppression xxx.
160	161	Frost crack.....	x	—	—	x	Frost.
81	163	Fire.....	x	—	—	x	Condition very poor; sup- pression x. Knots.
84	164	Knots.....	—	—	—	x	
3	165	Fire.....	x	—	—	x	
51	165	do.....	—	x	—	x	
24	166	(?).....	(?)	(?)	(?)	(?)	Notes incomplete.
82	169	Knot.....	—	—	—	x	Knot.
8	170	Fire.....	(?)	(?)	—	x	
57	170	Frost crack.....	—	x	—	x	Frost.
67	170	Knot.....	—	—	—	x	Knot.
64a	175	Fire.....	x	—	—	x	Suppression xxx.
64b	175	Lightning.....	—	x	x	—	
52	178	do.....	—	x	x	—	Advance rot.
77	180	Fire.....	x	—	x	—	
71	183	Lightning.....	—	x	—	—	
95	185	Fire.....	x	—	—	x	Suppression xx.
39	191	do.....	x	—	—	x	Dominance xxx; fire 110 years ago; deep burn.
86	192	Frost crack.....	—	x	—	x	Frost.
14	200	do.....	—	x	x	—	
142	200	Fire.....	x	—	—	x	Condition very poor; sup- pression xxx.
73a	221	Frost crack.....	—	x	—	x	Frost.
73b	221	Lightning.....	x	—	x	—	
59	232	do.....	—	x	—	x	
141	258	Fire with frost crack.....	x	—	x	—	Advance rot.

Table IV is designed to show whether and in which cases typical rot extends much beyond the wounds forming the entrance for the fungus. Column 7 is the one to be followed ("Typical rot, extending much beyond wounds"). The affirmative is expressed by a cross, x, the negative by a dash, —. Cases which are on the line between the two are marked by a cross in parentheses; they are negligible for our purposes. The first tree to be considered, No. 58, is 123 years old and has a frost crack. From this age, or rather after 126 to 130

years, these cases become more and more frequent. In most cases, to judge from this table, frost cracks are a strong factor for extending typical decay much beyond the point of entrance of the fungus. By splitting the bole for a considerable length they allow air to enter the wood, which evidently stimulates the growth of the fungus.

In noting the cases of decay traced to the wounds or openings through which the fungus found its entrance, it is seen that two and even more cases of decay (cull cases) may be found on the same tree, but each case is counted separately. Where decay is traced to a combination of two factors, each factor is shown separately. The means of entrance of the fungus causing decay are thus shown to be as follows: Fire, 48; frost, 25; lightning, 23; other causes (including knots, girdling, etc.), 13; total, 109.

These 109 wounds (including knots, etc.) led to 97 cull cases. Out of 109, only 13 were other than wounds from fire, frost, and lightning, and 11 of the 109 cases of decay were the effect of a combination of two of the causes named. Fire has by far the greater share; frost and lightning are second, but the preponderance of fire and frost over lightning is greater than would appear, since they are far more serious with respect to causing decay. If ratings are given, more or less arbitrarily, but yet in keeping with our field observations, to the various causes of wounds in the order of their importance with relation to damaging decay in white fir, taking injury from lightning (the least consequential) as the unit, we have: Fire, 3; frost, 4; lightning, 1; other causes (including knots, girdling, etc.), 3. Then, multiplying the figures for means of entrance by these relative ratings we have: Fire, 144; frost, 100; lightning, 23; other causes, 39. These figures express the following facts: (1) Fire injury is not only numerically the strongest, but also commonly leads to considerable cull; (2) frost damage is less frequent (above all, less ubiquitous) than fire damage, because it appears only in typical frost belts or frost holes, but it carries decay over a much greater length of the bole; (3) lightning injury is fairly common, is also restricted to certain belts, and leads more often to superficial rot; (4) other factors are of importance as causes of damaging decay, but they are comparatively rare.

CONCLUSIONS AND OUTLOOK.

The interpretation of the results of this study of the white fir from a practical point of view can not leave out of consideration the fact that the basis for all computations and tables is a comparatively small one and that the actual figures and many of the principles derived therefrom have more the value of strong indications for local application than the force of general laws. Still quite a number of the considerations will be directly applicable, at least in all similar types, some throughout the range of white fir. The writer would emphasize again that the aim of the present study is not to lay down laws, but

to show by means of one example the problems before us and the various steps leading up to a working method for the future establishment of laws which may—or may not—confirm the conclusions from this study, and to strongly advocate similar studies on a larger scale. With this point plainly in view, but assuming that our conclusions are a step in the right direction, we may discuss their bearing on the silvicultural problems that are before us.

DECAY IN RELATION TO WOUNDS.

In most cases, decay in white fir is caused by *Echinodontium tinctorium*. The mycelium never enters through the intact bark. Fire wounds offer the most common way of entrance; hence, in the majority of cases, decay starts in the butt; frost is less common than fire, but favors the vertical spreading of typical decay. Localized and superficial advance rot, frequently leaving enough merchantable timber in the log to make it worth while handling except when occurring in the upper part of the bole, is often connected with lightning. Other means of entrance, such as knots, wounds from falling trees, and girdling by rodents are comparatively rare.

These factors group themselves naturally into such as are uncontrollable and such as may be controlled directly or indirectly. The entrance of decay through knots, wounds from trees and limbs thrown in heavy storms, or from excessive snowfall lies beyond our control. Injury from mammals as a starting point of decay is very rare and will become even more so with the decrease of the forest fauna.

The other factors are more or less open to influence. Fire is distinctly a directly controllable factor. Lightning and frost are, of course, not directly controllable. It is a fact, however, that both do not occur to any damaging extent except in more or less well-defined belts, and generally more heavily in foci inside of these belts. The natural inference would be not to favor white fir in such belts when possible. As a first step in this direction the establishment and mapping of frost belts, frost holes, lightning zones, and lightning foci would be of particular value, which should not be confined to white fir alone. Other forest trees are also more or less subject to injury from both factors. The value of such maps should also make itself felt in forest-fire control, for the proper distribution of protective forces and improvements.

FOREST REGULATION.

CARE OF VIRGIN FORESTS.

It has been heretofore pointed out that practically the only means of silviculturally influencing the national forests on a larger scale at the disposal of the administration at the present time lies in the handling of timber-sales areas. On all the vast forests outside of these

comparatively restricted areas the same beneficial and injurious conditions must continue to prevail, which on one hand govern the annual increment and on the other make for annual total loss. Only one single component of the total-loss factor, though a most important one, may be controlled to a certain degree directly. Forest fires are in ever-increasing ratio eliminated from the national forests and, therewith, also the danger of trees being fire scarred and opened to the attacks of heartwood-destroying fungi. But the best of fire protection can not restore to their original state of intactness the overwhelmingly large number of older trees which have been opened by previous fires. The open fire wounds continue to offer an easy entrance to fungi. It is true that fire protection prevents small wounds from becoming larger and keeps healing wounds from being opened again by repeated fires. The sooner such fire-wounded trees, as well as all other undesirable individuals, including all badly injured, diseased, and misshapen ones, can be eliminated from the forest, the better. There is little hope, however, for this to be done outside of timber sales. Adequate fire protection, both of watersheds and of commercial timber, must of necessity be paramount to silvicultural work of this kind.

Practically virgin forests may also be influenced by sowing and planting. This is done on so small a scale, compared to the total of existing forests, that we can hardly speak of any real silvicultural change. Knowing, however, that white fir can not be expected to yield full returns in belts subject to lightning and severe frosts, the forester should avoid favoring white fir in such localities.

FOREST REGULATION THROUGH TIMBER SALES.

Cutting timber does not in itself constitute sound silviculture. It may lead to regulation, or it may spell ruin to the forest.

The administration of the national forests is not able to have timber cut by selling it where cutting is most needed. Accessibility, local demand, and last, not least, the quality and condition of the timber are stronger factors in finally locating a timber-sales area than silvicultural needs. A strong admixture of inferior species in itself is often sufficient to let an otherwise attractive sale fall through. Here, the prejudice of the purchaser against such species as white fir and incense cedar is responsible for forcing the Forest Service to leave an area badly in need of improvement in its virgin state, with all the cumulative risk to which it is exposed. The prejudice against white fir is widely established and not always confined to the lumberman.

From a silvical point of view the prejudice is directed against its very aggressiveness, which tends to give the species an ascendancy over the more valuable but less tolerant pines. But the disfavor in which it is held by the forester is really nothing but a reflection of

the strong objection made by the purchasing lumberman to accepting white fir in Government timber sales, and this is based mainly upon the unsoundness of the timber. At the same time, there is a fair local demand for sound white fir for a number of uses. There is no valid objection to clear and sound white fir. In fact, many a purchaser would rather pay higher stumpage for white fir if he were allowed to take only sound young stuff, which is in demand for dimension stuff (2 by 4, 4 by 4, etc.), for frame stuff, timbers, and stickers, and for butter boxes, etc. Purchasers complain that much of the material, though seemingly sound, "has no life" after going through the mill; it becomes brittle and falls to pieces when dry. Sound white fir neither becomes brittle nor does it fall to pieces. It is the unsound material (advance rot) only which is objectionable. The remedy is easily seen; it consists in liberal and judicious scaling, which would rather give the purchaser the benefit of the doubt. The scaler will find valuable aid in the occurrence of decayed knots on the boles of trees affected with stringy brown-rot. To the casual observer they may appear normal; when they are knocked off with a hatchet or similar instrument the decayed rusty interior is exposed. These "rusty knots" afford, in the vast majority of cases, a valuable indication of more or less far-gone *Echinodontium* rot in the heartwood of white fir. Occasionally, the rusty color is missing, but the center of the knot is unmistakably decayed. The verdict as to the rottenness of the heartwood will be the same. The knots are often very small. When sound, they are very brittle and glassy in appearance. To give a practical example:

No. 82 on the Otter & Burns tract, a very fine tree with a long clear bole, 29.4 inches diameter breast high, and 154 feet high, had been given a full scale. The bole had been bucked into 16-foot logs. To the scaler there were no indications of decay. After examining the tree the writer threw out log 5. The only indication for spotting *Echinodontium* decay in this log was the presence of the rusty knot. The log was opened and found to be unmerchantable from 0.5 to 5.6 feet from the lower end, leaving as merchantable 0.5 foot on one end (diameter 19.5 inches) and about 10 feet on the other end (upper diameter 16.3 inches). Had the defect been known to the bucking crew a more advantageous dividing up of the bole in log lengths to the exclusion of the decay would have meant a saving to the operator.

Among others, Bryant¹ has pointed out the necessity of more judicious bucking and of closer utilization.

¹ Bryant, R. C. Waste in cutting timber. *In Amer. Forest.*, v. 19, no. 11, pp. 790-799, 7 figs., 1913.

MARKING.

The entire silvicultural results obtainable by way of timber sales are directly dependent upon proper marking, the importance of which can not be overemphasized. Marking is by far the most portentous of all silvicultural activities and requires a very specific training, of which a complete knowledge of all components of the total-loss factor must be a prominent part.

Marking in the selection forest has a threefold object—to select trees to be cut and utilized at once, to leave others as a basis for future cuttings, and to establish desirable reproduction. Here the interests of the Government as timber owner and timber producer frequently conflict with those of the purchaser. The purchaser can not be expected to take a strong interest in the future of the area he is to cut over. He quite naturally wants as much sound merchantable timber from a given stand as possible. The larger the amount of timber he can cut from an area the smaller the overhead charges will be per thousand feet, board measure. In offering white fir for sale it is, therefore, important to be able to estimate more or less correctly the amount of sound timber on a given tract. If our figures prove correct, the loss factor in white-fir trees will be comparatively small up to an age of about 130 years; after trees with a combination of wounding and suppression have reached the age of 130 years they are liable to contain decay; after they have reached the age of 150 years wounding alone, even in dominant trees, is liable to lead to damaging decay. That trees with sporophores are decayed, at least partly, is self-evident. The actual cull per cent from decay is at present only guessed at. It is the constant aim of forest pathology to reduce this guesswork to actual and concrete figures. It is intended to repeat similar studies throughout the range of white fir and later also on other species in the order of their importance and finally to establish broad zones of equal pathological conditions, in which the rot percentage may be given in definite figures.

Marking can only be done correctly if the outcome of the marking with regard to the trees left standing is constantly kept in mind. In our specific case, for instance, white fir on typical lightning and frost belts should be marked very heavily. We know that here the loss from decay, particularly following frost cracks, is heavy and will grow through cumulative risk. White firs with serious wounds, especially with partly open fire wounds, must be marked heavily to as low a diameter as practicable.

On the other hand, thrifty unwounded trees, where desirable, may be left without much risk up to the age of about 150 years, and probably much longer.

The effect of logging on the pathological condition of white firs that are left on the area may be twofold. The opening of the crown cover through cutting will prove beneficial to all suppressed and intermediate white firs. The ready response of the species to light is well known. It is probable that such trees, if already infected, will not allow the decay to proceed very much farther, i. e., the newly formed upper logs may be sound. These trees move up into the dominant class. The mycelium in the heartwood, however, if well established, will not die out, and after a while sporophores appear which carry the disease to hitherto sound trees. As there can not be any infection except through spores coming from sporophores on diseased trees, it is evident that it is poor silviculture to leave individuals infected with any parasite of economic importance on cut-over areas. Such trees on timber-sale areas should be marked and cut under all circumstances if we expect to save and utilize the sound timber they may contain and to protect other trees from decay. Sanitation of the forest must be the first and fundamental step in forest regulation. The introduction of the so-called sanitation clause in the timber-sale contracts of the Forest Service aims at this very point.

It is evident that blind enforcement of the sanitation clause, following the letter and not the spirit of the principle expressed, is just as pernicious as laxity in its application. Not all parasites are of equal importance; our efforts should first be concentrated on the most dangerous ones. The time will come when forest sanitation will include all controllable elements making for loss in timber volume and timber values.

On the other hand, if only thrifty trees are left standing after logging operations, they are, by the very opening of the "forest screen," more exposed to flying spores from surrounding untreated tracts, but unless wounded they are in no great danger of infection. The smaller the tract, the more will this influence make itself felt. The improved conditions under which they grow will help them to either overcome or limit the extent of decay in case they do become infected. As long as we do not possess any exact figures on the recovery of white fir on cut-over areas, however, it is advisable to consider wounded white-fir trees left standing as unaffected by the opening up of the stand, at least during the transition period, that is, in first fellings. All these trees have grown up under unfavorable conditions, and the chances that they are lastingly injured are considerable. By the time second logging operations cover the area, it is to be assumed that a more profound knowledge of the life history of white fir will be at hand.

The choice of white-fir trees to be left on the area, with the expectation that they will be sound and merchantable at the next felling, depends altogether on their condition and the length of time probably elapsing until that felling takes place. Assuming that our figures

are correct and that the next cutting may occur, for example, in 30 years, we may with comparatively small risk leave thrifty unwounded trees of any age on the area; wounded but thrifty trees of more than 120 years are to be cut, wherever practicable, because in 30 years they will be over 150 years old, at which age trees of this class are more liable to deteriorate. Wounded trees which at the same time are suppressed should be eliminated. It is bad silviculture to leave individuals in the forest which not only do not produce the maximum of timber but which in all probability will prove a total loss and which occupy the place that should be fully stocked with trees promising a full and sound crop. In case of an emergency, such as occurs under very unfavorable market conditions or where the protection of young stuff is the most important feature, wounded and suppressed white firs left standing should not be older than 100 years, since in 30 years they will have reached their critical age—that is, 130 years. After they have reached this age it appears that damaging decay becomes prevalent in trees of this description. Very severely injured trees have, of course, no place in the managed forest. The same is true for unusually suppressed or unhealthy trees, unless it may be expected with reasonable certainty that the opening of the crown cover will benefit them materially. Trees with open fire scars and with open frost cracks should be cut in preference to those with lightning scars or those having wounds from falling neighbors. In short, all wounds reaching far into the wood are to be given a higher rating with respect to decay than superficial wounds unless the latter are unusually large.

PATHOLOGICAL ROTATION AND CUTTING CYCLES.

Since we may expect that cutting during the period of transition will practically eliminate all those trees which by their combination of suppression and wounding become subject to early decay (critical age), the age of decline forms the basis for what might be termed the “pathological rotation,” for want of a better expression. It does not indicate that a given species should most advantageously be cut in regular intervals expressed by the pathological-rotation age, but that it should not be cut at a higher age. It is really a factor limiting the rotation and therefore also the cutting cycle.

Rotation based on maximum volume alone can not be more than a makeshift during the transition period; logically it should be narrowed down to maximum-volume production of sound timber. Such species as *Sequoia gigantea* and *Sequoia sempervirens* are so resistant to decay that their pathology will not influence their rotation at all. In some of our valuable pines the pathological rotation will probably be very high, either coinciding with or reaching beyond the age of maximum-volume production. In white fir, incense cedar, and a

number of other so-called inferior species, the pathological-rotation age is presumably lower than the age of maximum-volume production. We must look to forest mensuration for final data to settle this point.

Barrington Moore¹ advocates a rotation based on the "period during which the rate of volume production is greatest or shortly after it, provided it is long enough to give the most valuable product."² Here, again, the pathological rotation will be the limiting factor, except for species in which the rate of greatest volume production possibly occurs at a lower age than the pathological rotation. That the value of lumber grades is bound to play a far more important rôle in the future than at present, with regard to rotation, is a foregone conclusion.

So far, we have considered only the rotation per species. In pure or almost pure stands the rotation of the unit is determined by the rotation of the species clearly dominating, not only numerically, but also in value.

As soon as two or more equally valuable commercial species appear together in about the same proportion, the rotation of the stand becomes "synthetic;" that is, the rotation for the unit is governed by the individual rotations per species. In the great majority of cases neither the representation of the species nor their individual values are the same. Nearly always there will be certain species more desirable than others, which latter then are classed as more or less inferior. A weak representation of inferior species with low pathological rotation will be without much effect upon the synthetic rotation of the unit. The stronger the representation of inferior species, the heavier will be their bearing on the synthetic rotation.

On many of the large private holdings of the West the inferior species are disregarded altogether; they are simply left standing in logging operations. Unless the logged-over area is burned, the representation of inferior species is then an unduly heavy one. They must necessarily dominate the stand in the future.

The national forests, on the other hand, will be the regulated forests of the future. In many of the national forests, particularly in the West, several species of unequal value are represented on the same unit in such a manner as to make each one a strong factor to be considered. Here, regulation of yield must be based upon synthetic rotation and synthetic cutting cycles. Rotation and cutting cycles for each species must be determined separately, each on the chosen basis of either maximum-volume production, or rate of maximum-volume production, or production of maximum value, limited in

¹ Moore, Barrington. Chapman's method of studying yield, p. 94, 1913. To accompany forest plan, Plumas National Forest, district 5. Appendix (continued), Silviculture. (Unpublished. Furnished by courtesy of the U. S. Forest Service.)

² See also Zon, Raphael, Balsam fir, U. S. Dept. Agr., Bul. 55, 68 pp., 2 pls., 8 figs., 1914. (See p. 67.)

every case by the age of decline. The synthetic rotation is figured on the basis of the specific rotations, under due consideration of representation and relative value of each species from a commercial and silvical point of view. The same is true for cutting cycles. It should not prove impossible to express both representation and relative value for each species in symbols, which, together with the specific rotation, would permit the balancing of each species against the others, and thus to arrive at the synthetic rotation of the entire unit. In this way the inferior species will be given their proper place in forest regulation. This procedure is undoubtedly followed more or less consciously wherever regulation is planned by way of timber sales. It can not be reduced to a practical working system, however, until all factors upon which it is based are thoroughly known.

The pathological rotation limits the rotation of white fir, on the basis of our present knowledge, to 150 years—at least during the transition period. Perhaps the actual felling age for the species will be shortened long before that time arrives. The chances of providing for the next decades are distinctly better. On areas cut over to-day we may expect second operations in not too remote a future, taking the place of a second improvement felling. Provided our figures prove correct, the critical age and the age of decline will be a safe guide in tentatively fixing cutting cycles for white fir, which, together with the cutting cycles for the other species present, will permit the establishment of the synthetic cutting cycle for the unit.

Our present knowledge of the pathology of white fir leads us to the following practical conclusions for the period of transition:

Prejudice against white fir as an inferior species.

Conservative scaling (excluding advance rot) in favor of the purchaser on the one hand and of better utilization of sound white fir (where market conditions permit) on the other will in time overcome the prejudice.

Silvicultural treatment of white fir.

Reproduction: Frost and lightning zones are to be avoided.

Marking on timber sales:

On frost and lightning zones marking should be heavy.

Badly wounded trees, particularly those with open fire scars or frost cracks, should be marked heavily.

Badly suppressed trees should be marked heavily.

Trees with a combination of wounds and suppression can not be figured on to remain fairly sound beyond the critical age of about 130 years. The age of such trees, if left standing, added to the number of years to elapse before the presumable next cutting takes place, must not exceed 130 years.

Trees wounded, though thrifty, can not be counted on to remain sound beyond the age of decline of about 150 years. The age of such trees, if left standing, added to the number of years to elapse before the presumable next cutting takes place, must not exceed 150 years.

Rotation and cutting cycles.

The rotation for white fir, as far as we can judge now, can not exceed 150 years.

Cutting cycles for white fir must be limited by the age of decline.

OUTLOOK.

The weak point in the example (white fir) discussed in this paper lies in the fact that the numerical basis of trees examined is insufficient. Besides, what may be true for one set of conditions may prove wrong in another. Extensive additional studies on white fir in different regions of its range have been carried out during 1913.

What has been done for white fir must be done for the other species as well. Investigations on incense cedar have yielded suggestive results; others are to follow. But not before all important species, from the lowest to the most valuable, have been studied carefully with regard to their pathology can we expect to definitely figure the total-loss factor for any unit. To-day we are standing at the very beginning. Each species has its specific fungi, either one (as in the case of incense cedar), or practically one (as in the case of white fir), or several (as in the case of Douglas fir, sugar pine, and yellow pine). The relative importance of each of these fungi, their relation to influencing factors, their prevalence throughout the range of their hosts, and, finally, the establishment of the critical age and age of decline from a pathological point of view, are still to be worked out. To this we must add the study of all the other components of the total-loss factor.

The amount of work left to be done is enormous and will require many years. Concentration on the inferior species will yield results in a shorter time, enabling us to establish general rules to guide us in the transition period without causing too much damage to the interests of future generations.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 251

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

July 27, 1915.

THE CALOSOMA BEETLE (CALOSOMA
SYCOPHANTA) IN NEW ENGLAND

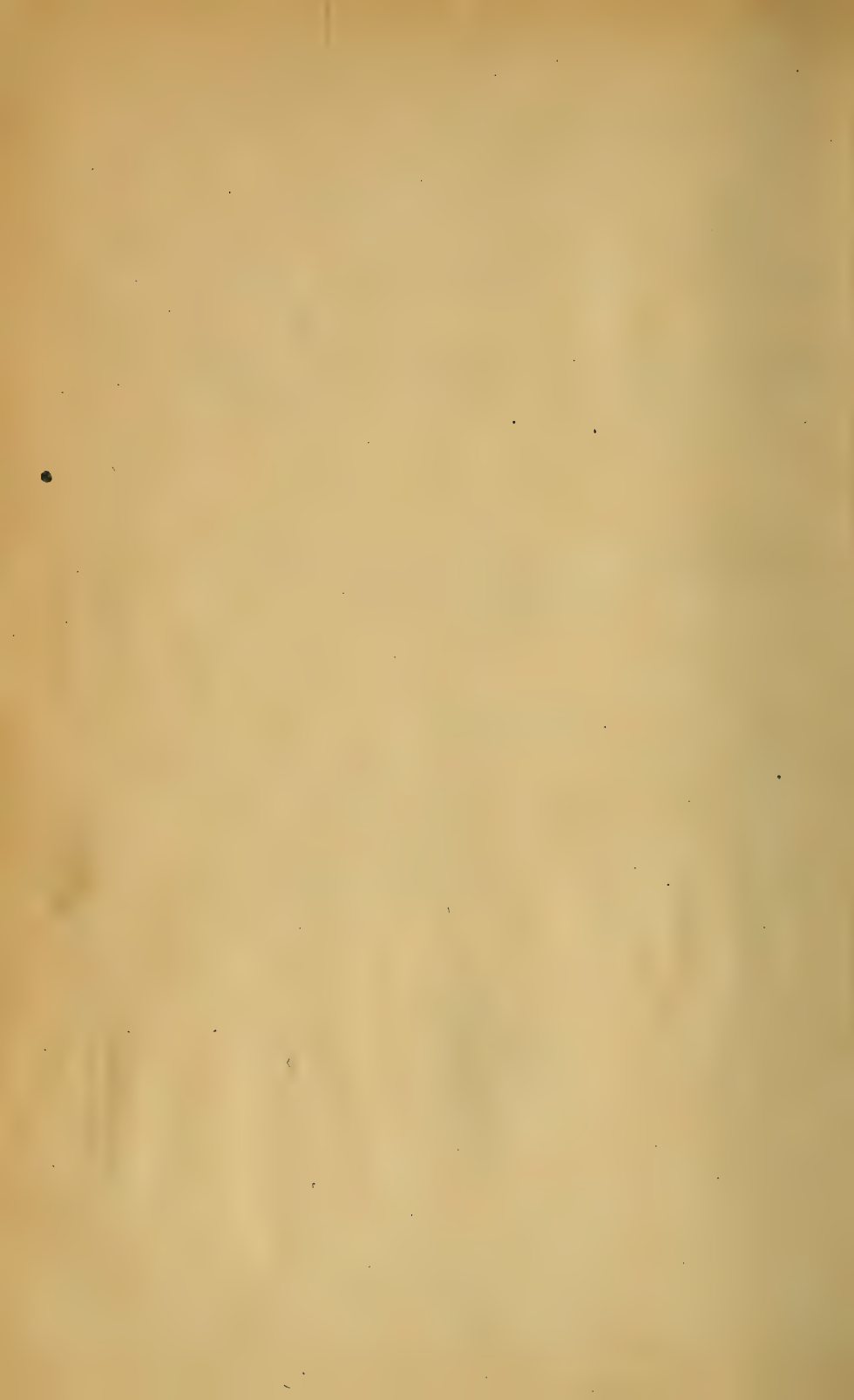
By

A. F. BURGESS, In Charge of Gipsy Moth and Brown-tail
Moth Investigations, and C. W. COLLINS
Entomological Assistant

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 252

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

August 10, 1915

LIFE HISTORY OF THE CODLING MOTH
IN MAINE

By

E. H. SIEGLER and F. L. SIMANTON, Entomological
Assistants, Deciduous Fruit Insect Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 257

Contribution from the Office of Public Roads
LOGAN WALLER PAGE, Director

Washington, D. C.

PROFESSIONAL PAPER

July 12, 1915.

PROGRESS REPORTS OF EXPERIMENTS
IN DUST PREVENTION AND ROAD
PRESERVATION, 1914

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 258

Contribution from the Office of Experiment Stations
A. C. TRUE, Director

Washington, D. C.

July 13, 1915.

LESSONS IN
ELEMENTARY AGRICULTURE FOR
ALABAMA SCHOOLS

OUTLINED BY MONTHS

By
E. A. MILLER, Specialist in Agricultural Education

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 268

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ July 20, 1915.

CROP PRODUCTION IN THE GREAT
PLAINS AREA

RELATION OF CULTURAL METHODS TO YIELDS

By

E. C. CHILCOTT, Agriculturist in Charge, and J. S. COLE
and W. W. BURR, Assistants, Office of
Dry-Land Agriculture

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 270

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.



July 29, 1915.

CEREAL EXPERIMENTS AT THE
WILLISTON STATION

By

F. RAY BABCOCK, Scientific Assistant, Office of
Cereal Investigations

(In cooperation with the North Dakota Agricultural Experiment Station)

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 271

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WM. A. TAYLOR, Chief

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PROFESSIONAL PAPER

September 28, 1915

DATES OF EGYPT AND THE SUDAN

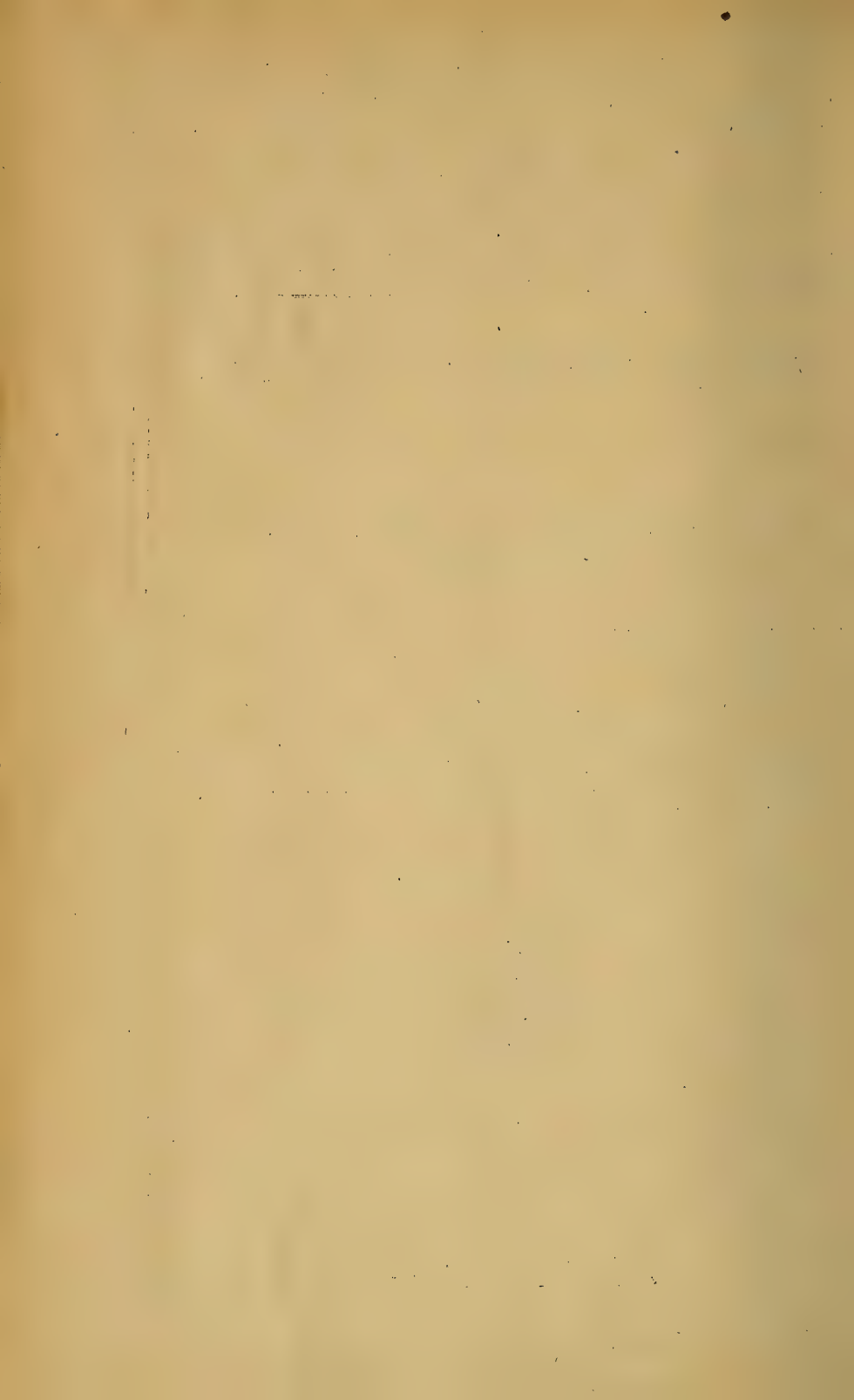
By

**S. C. MASON, Arboriculturist, Crop Physiology and
Breeding Investigations**

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 272

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.



September 27, 1915

THE SOUTHERN CYPRESS

By .

WILBUR R. MATTOON, Forest Examiner

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 274

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.



July 8, 1915.

FACTORS GOVERNING THE SUCCESSFUL
SHIPMENT OF RED RASPBERRIES
FROM THE PUYALLUP VALLEY

By

H. J. RAMSEY, Pomologist in Charge of Fruit-Handling and
Storage Investigations, Office of Horticultural and
Pomological Investigations

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Chief of Bureau, WILLIAM A. TAYLOR.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 275

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER April 7, 1916

**FOREST PATHOLOGY IN FOREST
REGULATION**

By

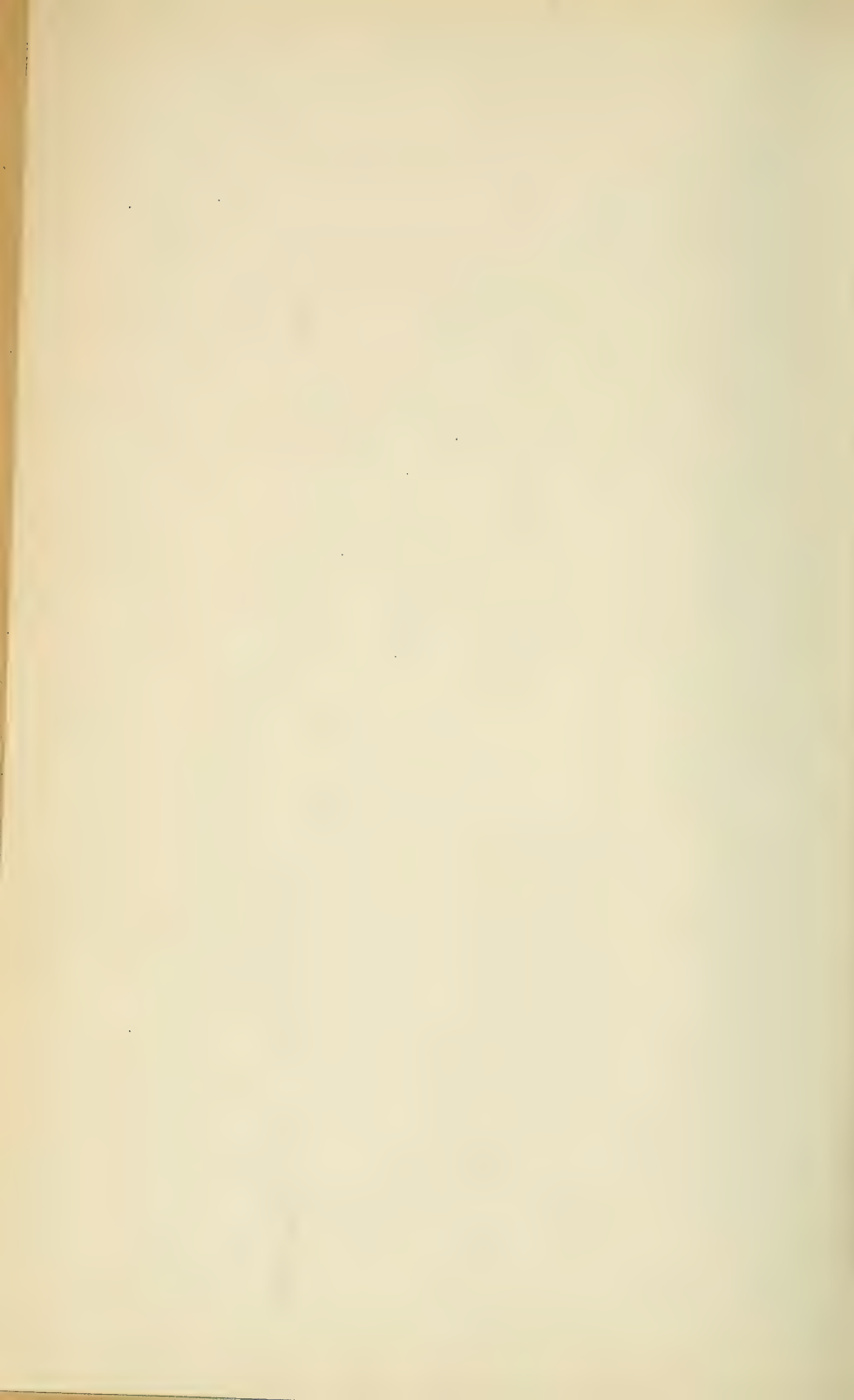
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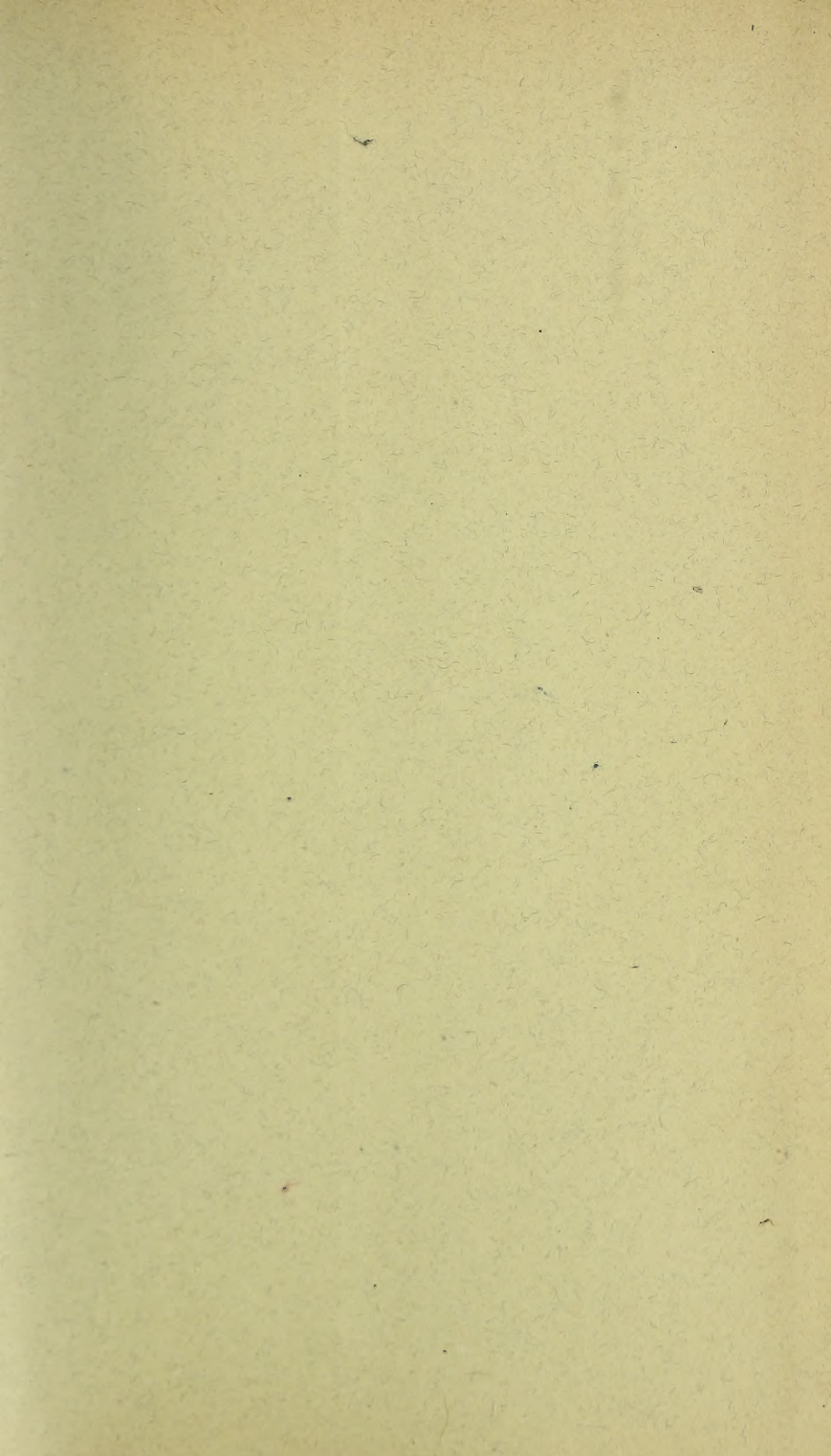
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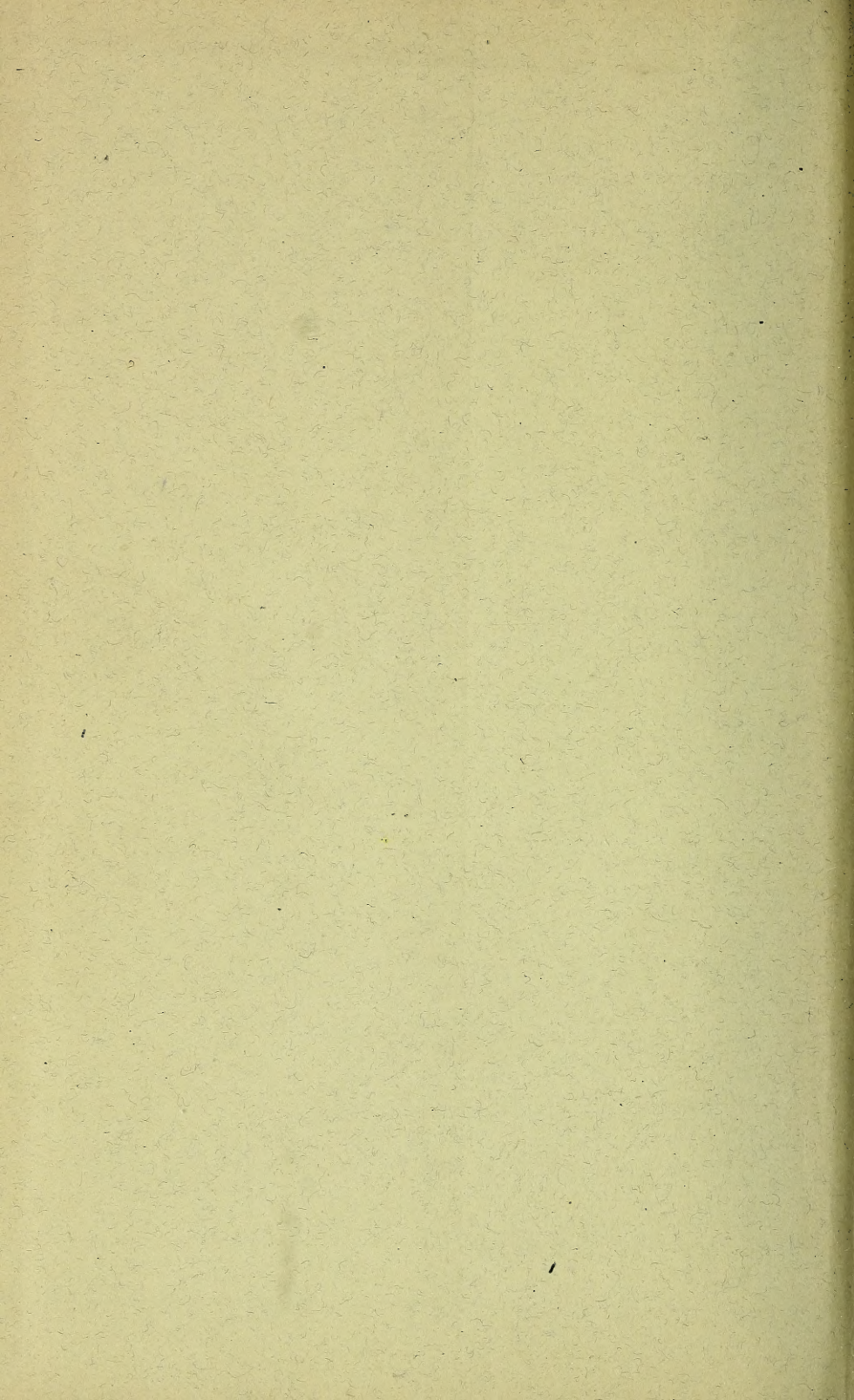
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